Infrastructure to 2030

TELECOM, LAND TRANSPORT, WATER AND ELECTRICITY




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Preface

Following an extensive international consultation process with government departments and agencies, corporations and research institutes, the OECD International Futures Programme launched a two-year project in the Spring of 2005 on "Global Infrastructure Needs: Prospects and Implications for Public and Private Actors". This publication is an interim report, reflecting findings to date.

The purpose of the project is to take stock of the long-term opportunities and challenges facing infrastructures worldwide, and to propose a set of policy recommendations to OECD governments that aim to enhance infrastructures' contribution to economic and social development in the years to come. The project has a time horizon out to 2020-30. It covers energy, surface transport, water and telecommunications, and focuses on OECD countries and some of the so-called Big 5 economies (Brazil, China, India, Indonesia and Russia). One of the expected benefits of this multi-sectoral approach to infrastructures is that it will generate interesting common lines of enquiry and give rise to instructive cross-sectoral implications.

The project is being funded by voluntary contributions from governments, public agencies and corporations, who are represented on the Steering Group. The Steering Group advises the OECD Project Team on the content and direction of the project. (The reader will find a list of the Group's members at the conclusion of this publication.) Countries represented are Canada, Denmark, France, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. The Steering Group met for the first time in June 2005 and held a second meeting in December 2005. Two further meetings are scheduled for June and December 2006. The report, together with the policy recommendations, will be finalised end-2006 and published in 2007.

The work is being conducted in five phases: 1) Assessment of future demand for infrastructure investment; 2) Identification of critical issues for the future; 3) Consideration of the future viability of current business models; 4) Improving the institutional and framework conditions; 5) Conclusions and recommendations.

This publication presents the results from the first and second phases of the work. It is based on a series of expert papers whose purpose was to establish a broader picture of trends and developments that are likely to impact on infrastructures and infrastructure investment over the next few decades, and to assess how the longer-term future may unfold in each of the infrastructure sectors under review – electricity transmission and distribution, surface transport, water, and telecommunications and *broadband. In addition to the drivers traditionally reviewed in such forward-looking studies (economic growth, population, income levels, etc.), the authors have explored the potential impact on infrastructure development of other factors such as climate change, security issues, the likely evolution of public finances, human settlement patterns, and technology-induced substitution effects. All the papers in this volume have benefited from expert advice and comment from the Steering Group.*

The project is being led by the OECD's International Futures Programme, a forward-looking multidisciplinary unit which provides the OECD Secretary-General and the Organisation with early warning on emerging policy issues. It does this by identifying major developments and analysing key long-term concerns to help governments map strategy. Its role is also to promote horizontal, cross-Directorate themes in the OECD. Hence, the work is being conducted in co-operation with several OECD Directorates and Agencies, notably: the European Council of Ministers of Transport and the Joint Transport Research Committee; the Environment Directorate; the Directorate for Science, Technology and Industry; the Statistics Directorate; and the International Energy Agency. The project has already benefited substantially from inputs and comments from colleagues in those parts of the house.

Barrie Stevens directed the work of the authors and the preparation of this publication. Pierre-Alain Schieb is initiator and co-ordinator of the project. Michael Oborne is Chairman of the project Steering Group. Technical support was provided by Anita Gibson, Concetta Miano and Manon Picard, and editing by Randall Holden.

This volume is published on the responsibility of the Secretary-General of the OECD.

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Infrastructure to 2030
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Chapter 1

A Cross-sectoral Perspective on the Development of Global Infrastructures to 2030

by

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Infrastructures are at the very heart of economic and social development. They provide the foundations for virtually all modern-day economic activity, constitute a major economic sector in their own right, and contribute importantly to raising living standards and the quality of life. However, infrastructures also have less desirable consequences. To name but a few – more roads may mean more traffic and more noise, power plants may add considerably to greenhouse gas emissions, and dams may entail the destruction of large areas of countryside and the displacement of population. The next decades are likely to see an accentuation of two facets of infrastructures. On the one hand, they will prove a vital tool in resolving some of the major challenges faced by societies – supporting economic growth, meeting basic needs, lifting millions of people out of poverty, facilitating mobility and social interaction. On the other, environmental pressures in the form of changing climatic conditions, congestion and so on are likely to increase, turning the spotlight firmly on the inherent tensions between the imperative for further infrastructure development and the quest for sustainability.

This is just one good reason for taking a long-term perspective on infrastructures – there are others. Infrastructures usually last a very long time, often generations, and also take a long time to build, so that bringing about change in their systems requires long-range thinking and vision. Moreover, globalisation is intensifying economic and other interlinkages among countries, making it increasingly necessary to plan, develop and finance infrastructures across national borders. The key players too change over time, as the roles and responsibilities of the public and private sectors shift and evolve. Such changes underscore the importance of taking a longer-term view of both the objectives of public policy – economic, social and environmental – and the regulatory and institutional framework within which they are pursued.

Hence, the next 25 years offer a useful time frame for exploring many of the issues that will need to be tackled if these various challenges are to be addressed successfully. How much investment in infrastructures is likely to be required, and what are the forces – economic, demographic, technological and environmental – shaping those requirements? How will they be financed? What difficulties is the management of infrastructure likely to confront?

These are some of the key questions this publication sets out to explore. In so doing, it will highlight the importance of considering infrastructure not just as distinct sectors but also as a series of interdependent systems.

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The infrastructures covered in this publication – land transport, electricity, telecommunications and water – have for many years now shown signs of increasing convergence. The various systems interact ever more closely with one another and engender all kinds of synergies, substitution effects and complementarities, but also in some cases heightened vulnerability to disruption, technical failures and malicious attack. Policy makers need to take a holistic approach to infrastructure development and consider what infrastructure mix may be desirable in light of the tradeoffs that will have to be made between the various policy objectives. (For example, environmental concerns may lead to attempts to shift traffic from roads to rail or to increase the share of renewable energy sources, but without unduly constraining economic development.)

This introduction is organised as follows. In order to put infrastructure development into a proper overall policy perspective, it begins with a brief overview of the economic, social and other benefits that infrastructures have generated in the past and might be expected to provide in the future, before turning to the question of the most important factors likely to shape the development of infrastructures in the coming years. After summarising the findings of projections on future investment requirements from each of the sectoral chapters, it addresses some of the specific interdependencies among the different infrastructure sectors. Finally, it draws out a number of relevant cross-sectoral issues and policy challenges, and then reflects briefly on the way ahead.

1. Benefits from infrastructure – past and future

The economic benefits of infrastructure have been the subject of much debate since at least the 1980s, with the discussion focusing on both the direction and magnitude of the effects. While it is possible to establish a link between infrastructure development and economic development, it is difficult to ascertain the direction of the causation: does infrastructure contribute to economic development or *vice versa*? Moreover, there was considerable scepticism about the initial estimates of the productivity gains stemming from investment in public infrastructure. Over the past few years however – with improved data, new methodological approaches and refinements to models – there has been much less controversy. A review of the more recent literature suggests that public infrastructure has a positive productive effect on the economy, but that the size of the effect is not as large as that estimated by earlier studies [such as those by Aschauer (1989)]. Based on samples of several OECD countries and broken down according to economic sectors, the findings indicate that the efficiency impacts of infrastructure tend to be positive – but relatively modest – in almost all sectors.

What is important to note is that the returns on infrastructure investment take time to materialise. The more recent studies indicate that the long-term impact of infrastructure on the economy is positive, and that while an increase in investment in public capital acts as a substitute for private capital initially, in the long run the dominant effect is one of complementarity. However, it would appear that investment in infrastructure does not, on the whole, create (directly) long-term employment. The studies also suggest that patterns of underinvestment in infrastructure in some countries may have something to do with the difficulties governments experience in estimating the overall long-term effects of infrastructure on the economy. Making the “right” decision regarding infrastructure development is often difficult because of the public good nature of the benefits (how much is enough, who should benefit). Moreover, the broader impact of infrastructure is clearly conditional on how efficiently it is used. Poorly managed or poorly conceived infrastructure does not necessarily generate the same return.

The productive impact of an infrastructure depends not only on the magnitude of the investment, the project’s design and efficient management, but also on the nature of the investment and its integration into an existing set of infrastructures, *i.e.* how it improves the network. Thus, first infrastructures only have limited impact on private sector productivity since their effect is primarily local. The addition of new infrastructures to create a network, however, allows considerable productivity gains by extending the use of existing infrastructures to everyone. Subsequently, when the network is largely completed, the addition of new infrastructures again has only limited impact, if any, on private sector productivity.

But such additions can still have an effect on the economy, namely by making the regions in which infrastructures are abundant more attractive and thereby enhancing their competitiveness. This in turn may give rise to relocation of factors of production among regions. Attractiveness is therefore a factor, irrespective of whether the infrastructures lead to productivity gains. The political dimension of this process is clear, since it will benefit some regions at the expense of others as they compete among themselves to attract labour, capital and know-how. From an overall economic perspective, this highlights the importance of conducting cost/benefit analyses for large projects that also take into account the loss of attractiveness of those regions not concerned by the new infrastructure. Attention should also be paid to consumers’ intrinsic evaluation of the infrastructure since this can generate knock-on effects, for instance in the form of higher property prices.

What of the eventual economic benefits of infrastructure? As more and more networks are completed, for example, will the economic benefits stagnate? Generally, this seems less likely. As Stamford points out in his chapter on land transport, notwithstanding political factors that may have resulted in some

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uneconomic projects going ahead, it can be assumed that in OECD countries most of the transport infrastructure investments over the past 20 years have been cost-beneficial; and that it is very likely that some amount of cost-beneficial new construction has been constrained by limited availability of public finance. Moreover, in most of the so-called Big 5 economies (Brazil, China, India, Indonesia and Russia) and developing countries, there has been chronic underfunding of transport and other infrastructure, also reflecting limited public finance availability. On these assumptions, it seems safe to say that also in future, the benefits of road infrastructure spending will exceed the costs.

In comparison with the economic benefits generated by infrastructure, the value of infrastructure as a contributor to higher living standards and quality of life has received much less attention. Yet it is likely to be very high, given that households and private individuals are heavy users of infrastructure systems. Part of the problem is that the value of unpriced goods is difficult to measure. However, broad indicators of infrastructure availability can give a flavour of the difference to living conditions that infrastructures may make.

By way of illustration, it is clear that the coverage of 98% of the population in developed countries with sanitation services produces health and welfare outcomes greatly superior to developing regions with an average of only 49% coverage. More concretely, since in some cases health and welfare outcomes can in fact be approximated, it is estimated for the developing regions of the world that the benefits of halving the proportion of people without access to improved water sources by 2015 would be 9 times the costs incurred. Universal access to improved water and sanitation services by 2015 would generate an even higher benefit/cost ratio, in the range of 10. (See the contribution by Ashford and Cashman.)

By the same token, raising worldwide electrification rates from 74% in 2002 to 83% in 2030 (as projected by the IEA in the *World Energy Outlook*, 2004) would provide millions of people with electricity for the first time, contributing hugely to social development through education and public health, satisfying more effectively basic human needs of food and shelter, and reducing use of traditional biomass for energy purposes, with attendant benefits in terms of slower deforestation. Similarly, the rise in the number of mobile telephone service users across the globe from 800 000 in 2004 to over 5 billion in 2020 (see the chapter by Bohlin, Forge and Blackman) holds out the promise of greatly enhanced access to communications and vastly improved mobility for millions of people. This could also have major overall economic benefits, by raising productivity and accelerating the diffusion of knowledge.

2. Driving forces, trends and uncertainties affecting the longer-term outlook for infrastructure investment

A whole host of factors driving the development of infrastructures need to be taken into account in any forward-looking analysis of long-term investment requirements. The core assumptions underlying almost all projections of this kind concern economic growth (GDP) and population. But other driving forces may also affect the projections, thereby constituting an important source of uncertainty. While in shorter-term projections some of these drivers may be assumed away as playing only a minor role, they cannot be ignored realistically when a longer-term time frame is considered, as is the case here. Even if only a qualitative and highly tentative exploration of their impact can be made, it is important to do so for policy purposes. This helps policy makers better understand the risks involved in the projections and the consequences this may have for policy.

The authors of the sectoral chapters in this volume have explored a range of drivers and uncertainties from a variety of perspectives.

Geopolitics

All the authors acknowledge explicitly or implicitly the role played by geopolitical factors and their interaction with infrastructure development (though none of the papers takes into account the possibility of a major conflict that could seriously disrupt the economic and political environment in the coming decades). Bohlin *et al.* stress in particular the important role played by telecoms as a political asset for popular movements and its ability to change the balance of government and to contribute to the decline of the nation state. Morgan is not as explicit in the IEA paper, but he acknowledges that concerns related to the need to ensure the reliability and security of supply – which involves geopolitical considerations – is likely to influence investment decisions, for instance with regard to the fuel chosen for generating electricity (*e.g.* nuclear power in France and coal in the United States). Security of supply considerations may also influence the direction of research efforts to find alternative sources of energy or make existing ones (*e.g.* coal) more acceptable from an environmental point of view.

The geopolitical dimension may be less important for land transport than it has been in the past, but the critical role of road and rail for international connectivity is acknowledged. In the case of water, geopolitical considerations relate particularly to the potential conflicts that may arise among countries sharing water resources (see Ashley and Cashman). Some 40% of the world's population live in the 250 major river basins shared by more than one country. In Africa one-third of all water flows through the Congo, while only a tenth of the population lives within its basin. Economic development in Sudan and

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Ethiopia will draw on the Nile's waters, making the potential for conflict with adjacent states a real concern. Notwithstanding a number of established international mechanisms for mediating the problems of shared water resources, there is ongoing potential for water-related problems to contribute to regional tensions, such as in the Middle East (surface water resources) and Palestine (groundwater). Like Bohlin *et al.*, Ashley and Cashman see a decline of the nation-state as it is hollowed out upwards to the benefit of supranational organisations and downwards through devolution.

Security

Infrastructures need to be as resilient as possible so that when disruptions occur, their consequences are as limited as possible in time and scope. In recent years, concerns about infrastructure security have grown. Societies' dependence on infrastructure services has increased, and the consequences of major disruptions can be very serious indeed. Moreover, the scope for disruption has increased, as critical infrastructures become more closely interlinked and the activities of organised crime and terrorist groups take on a wider international dimension.

All the authors recognise the importance of security considerations. Bohlin *et al.* note that security concerns will be a significant driver of telecom infrastructure development. Moreover, they point out that the Internet will become a prime target of economic threat, forcing the development of a security architecture that assures not only that operations are secure, but also that the privacy of the individual is respected.

In the IEA chapter, Morgan stresses as well the importance of security considerations and the need for investment in upgrading and improving system operating tools that would enhance operators' capacity to effectively monitor, understand and more flexibly control transmission systems in real time. The chapter also notes that there is enormous potential for developing and deploying appropriate technologies for this purpose as well as for improving the quality of service.

According to Stambrook, safety and security considerations are also important for land transport. They are not considered a particularly new problem as far as road transport is concerned, since such considerations are already built into the estimates. The author, however, notes that security concerns may affect modal choice. Recent experience with terrorism targets and accidents suggests that travellers may in the future prefer the security of road transport relative to rail, in addition to the time and flexibility advantages. It is unclear whether (relative to air) there is a clear security/safety benefit for high-speed rail. Hence, additional security/safety costs are likely to be required to be built into rail systems to counteract these travellers' concerns.

Water facilities are also vulnerable to security threats. Certainly in North America the risk of malicious attack is becoming an increasingly important factor in infrastructure investment decision making. Attack could take the form of direct action to contaminate water supplies. But widespread disruption would likely be effected more easily via cyber attack, disrupting power, communication and control systems. The effects can be demonstrated by the power failure in the northeastern United States in August 2003, in which a number of wastewater treatment plants failed, leading to environmental pollution and households being advised to boil water (Ashley and Cashman). This illustrates the interdependencies across infrastructures and the need to take a holistic approach to security.

Economic growth and structure

In all four chapters, economic growth, notably growth in per capita income, is acknowledged as the major determinant of the growth in the demand for infrastructure. Indeed it is the only variable explicitly used in the projection exercise with the exception of the chapter on water, where an attempt is made to quantify the impact of four drivers of change (socioeconomic, technology, environment and political) on projected expenditures for water infrastructure as a percentage of GDP after 2015. Bohlin *et al.* note that increased income will drive all forms of telecom takeups, most specifically mobile. At the same time, telecom will drive economic development and will contribute to reducing income inequality across countries, as the main expansion of the telecoms network will take place outside the developed countries.

Morgan notes in the IEA chapter that the demand for electricity is closely related to changes in gross domestic product. Over the past 30 years the global economy grew by 3.3% a year while electricity demand grew by 3.6% with a very close tracking between the two variables. However, this remarkable stability in the relationship between GDP and the demand for electricity at the aggregate level hides striking differences between OECD countries, where the amount of electricity per unit of output produced has declined over time, and developing countries, where it has risen. Hence, changes in the structure of economic activities play an important complementary role to GDP growth. In this regard, a key question for the future is how fast the industrial mix in developing countries is likely to evolve, notably how fast the share of services will expand. For instance, over the next ten years it is expected that employment in the service sector will increase much faster than total employment in countries such as India and China, suggesting perhaps a substantial decline in the energy intensity of output at the margin in these countries. One should remain cautious in this regard since employment mix is not closely linked to output mix and hence to input mix. It is true that manufacturing employment in developing countries is not expected to increase much in the future. However, the manufacturing sector is the major

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source of labour productivity growth. In this context, increasing the output/labour ratio means that even if employment growth is modest, output growth and resource use growth may be substantial indeed.

GDP per capita is acknowledged as the main determinant of the demand for land transport, but various measures of road usage are also related to income: estimates of the elasticity of vehicle stock with regard to income vary between 0.75 and 1.25, with the elasticity of vehicle distance driven with respect to income in the 0.2-1.60 range. However, the link between per capita income and the demand for rail transport is not as clear-cut, since the expansion of rail, notably passenger rail infrastructure, is driven more by policy considerations (notably sustainability considerations) than by revealed consumer preferences.

GDP growth is also a main driver of the demand for water infrastructure and affects as well the ability of countries – notably developing countries – to carry out the necessary investment. In this regard, Ashley and Cashman note that if developing countries overall grow faster than developed countries over the next three decades, as suggested by World Bank projections, there should on the whole be a proportionately greater ability to pay for water services in the future (a notable exception being sub-Saharan Africa). Also important here is the development of international trade. As Rosengrant *et al.* (2002) point out, if trade in agricultural products increases in the future, this will be a way for water-poor countries to acquire water-intensive products and specialise in the production of goods requiring limited amounts of water.

Finance

Given the large amount of resources needed for infrastructure development, financial considerations – including the role to be assigned to public and private investors – play a key role in infrastructure investment.

In the case of telecommunications, the substantial funding needed for infrastructure upgrade and expansion will be largely carried out by private actors. Hence, the health of the lending market is essential (Bohlin *et al.*).

IEA also stresses the importance of access to capital for electricity investment. While such access is relatively easy in OECD countries where capital markets are well developed, the higher risks brought by market liberalisation and the uncertainties regarding future environmental policies will increase investment risks for operators in the coming decades – hence debt servicing charges are likely to rise.

In non-OECD countries, the situation is much more critical. First, capital markets are not well developed. More importantly, the private sector is being called upon to finance a larger share of electricity investment than in the past, in an economic, political and regulatory environment where the profitability of such investment appears highly problematic. Whether the capital needed can be mobilised quickly enough in this challenging context is a major uncertainty for the future. It may prove less so for countries with traditionally high saving rates.

Stambrook notes that in land transport, where the public sector plays a dominant role, the biggest challenge will be the public willingness-to-pay for increased land transport mobility – either through general taxation (as mediated by public finance authorities), specific taxation (where this exists) or user charges (including in support of private participation *i.e.* PPP). It is further noted that given individual users' preference for road transport over rail, there is no "sustainability" fiscal dividend involved in any attempt to favour rail over road. Whatever they do, public finance and transport authorities will have to spend more on road infrastructure in the future or face dire economic and political consequences. At best, spending more on rail will only moderate the future increase in road infrastructure spending, not eliminate it.

Finance plays a key role in the water sector as well. An important trend has been the growing use of private capital as a way to shift the burden of funding from the public to the private sector. On the face of it, the water sector should be an attractive prospect: it is an essential service; it is technologically relatively low in risk and if reasonably well managed, offers steady though not spectacular returns. However, Ashley and Cashman note that private investment in the water sector is not without problems, as experiences in South America, South Africa and the Philippines suggest. Despite these difficulties, the involvement of the private sector in the public provision of services such as water is likely to grow in importance – especially given the huge engineering and financial challenges to be faced either in the provision of new infrastructure or the maintenance of existing assets. The nature of the relationship between the public and private sectors in this regard will have to evolve from the present models in order to gain greater political and social acceptance, especially in developing countries. Notwithstanding the possible growth in the role for the private sector, there is also potential for some forms of public financing, *e.g.* user fees, and the wider use of bonds.

Demography

Together with economic development, population growth is considered the most important driver of the demand for infrastructure. However, it is not the only demographic factor at play. For instance, Bohlin *et al.* acknowledge the importance of population ageing, of urbanisation in the developing world and of international migrations as important determinants of the expansion of telecom networks. Increase in the number of households could also be a factor here, as it is in the case of electricity.

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The IEA chapter also notes that changes in the level and age composition of the population affect the level and composition of electricity demand, directly and through its impact on economic growth and development. Ageing increases the number of households and therefore per capita electricity consumption. Migration also affects the need for new capacity investment in production transmission and distribution.

In the case of land transport, Stambrook points out that, together with GDP growth, population growth is the most important determinant of growth in the demand for infrastructure. He also points to the significance of population density, notably for the development of high-speed rail (HSR). However, he sees population ageing as having only an indirect effect, *i.e.* as putting pressure on health care systems and leading to many competing policy pressures for limited public funds – especially with the apparent "cap" on taxpayer willingness-to-pay. This position contrasts interestingly with the view expressed in other studies where population ageing is perceived to have an important impact on peak infrastructure use, a major determinant of infrastructure requirements.

Demography will also be a major determinant of the demand for water infrastructure. In developing countries, the rapid growth of population in urban areas, coupled with the pressures of economic growth, will give rise to considerable demands for water services both to provide industry with a base resource and also for the survival of the population. Given the low level of income of the majority of the population, the challenge will be to provide and extend a basic level of service to the burgeoning population centres at an affordable cost to both government and citizens alike. In the developed world, shifting patterns of human settlement may put sustained pressure on freshwater resources in some regions, possibly leading to tensions between urban and agricultural communities over priority setting for water use. However, the challenges are more likely to arise as a result of the consequences of population ageing (and the attendant increase in the number of households) rather than the need for new water services, given that the overall population will be stable. Indeed the rising expectations and relative wealth of their populations may well result in calls for higher levels and different forms of service from the existing infrastructure (Ashley and Cashman).

Technology

Technology plays a role in the development of all infrastructures, but its importance varies across sectors. Past experience also suggests that technical change is highly unpredictable and can have far-reaching impacts on infrastructure (*e.g.* the impact of mobile telephony on fixed line infrastructure, and of the Internet on the telecommunications sector and the economy at large).

Technology is considered particularly important for telecoms, as it is likely to be a driver behind the very rapid expansion of telecom networks expected in the coming decades by bringing about drastic reductions in communications costs (Bohlin, *et al.*). Particularly significant in this regard will be the widespread adoption of VoIP, further progress in fibre optic, greater data processing capabilities, the development of new mobile technologies, the introduction of location-based services, the further miniaturisation of equipment, progress in storage capacity, improved batteries and the development of local energy technologies for powering telecom equipment. Moreover, RFID could change logistics and medical care infrastructure services and will require new infrastructure for their effective implementation. In addition to the prospects identified by the authors, there may prove to be greater than expected potential both for space telecommunications (*e.g.* development of intelligent satellites and routers in the sky with onboard processing and multiple spot beams) and for the convergence of content and carriage (*e.g.* development of virtual reality applications). However, given the rapid evolution of technology in this sector, it is important to keep in mind that any attempt accurately to anticipate change over a 30-year period is obviously an impossible task. In particular, it is impossible to anticipate what technology will find widespread acceptance.

Technological change is expected to proceed at a more sedate pace in the electricity sector, although technical progress in telecoms could have important spillover effects for the management of electricity networks. According to the IEA chapter, technical advances will be reflected in part in the improved energy efficiency of electrical equipment, notably in developing countries. This could moderate increases in the demand for electricity in these countries, but it is not clear by how much. New technology could also contribute to cut distribution losses, thereby reducing the need for generating and transmission capacity. The choice of generating technology [*e.g.* natural gas-fired combined-cycle gas turbine (CCGT)] affects the size and location of power plants and therefore the need for transmission capacity. For instance, the volatile production patterns that result from a high proportion of renewable energy supply most likely mean increased investments in the grid, since it has to be particularly robust in order to secure reliable supply from both conventional and renewable energy production plants. However, technological factors need to be balanced against other factors, notably security of supply considerations. For instance, growing concerns about the reliability of supply of gas from Russia may dampen somewhat the enthusiasm for gas-fired electricity generation in Europe. On the other hand, technological progress may have important geopolitical consequences. For instance, over the long term, effective carbon sequestration could considerably strengthen the position of coal over oil and gas, and favourably influence the geopolitics of energy for consuming countries. And the successful development of long-life batteries could significantly accelerate the widespread adoption of electric cars.

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Technology seems to be least important for land transport. Stamford does not anticipate breakthrough technologies over the 2000-30 period that could fundamentally affect land transport demand. High-speed rail (and Maglev) technology is already around and tried. Improved vehicle technology (*e.g.* fuel efficiency, fuel technology) and vehicle design can offer substantial environmental benefits but should not affect the demand for road infrastructure. And ICT-inspired improvements in road capacity utilisation will probably only operate at the margin of incremental demand, although other studies do suggest a greater influence over the longer term.

By contrast, technology could play a key role in the development of water infrastructure in the future. First, advances in information technology and communications coupled with space technologies such as Earth observation could lead to a much greater ability to monitor all aspects associated with water-related service provision – the circumstances and the events surrounding it – in greater detail and to a greater extent than is currently technically possible. Second, biotechnology could significantly improve pollution prevention, monitoring and remediation. It has the potential to completely revolutionise water treatment processes and may well enable service providers to dispense with conventional treatment plants as they are known today. Much of the treatment would not require a large capital investment for the provision of large fixed infrastructure, as this would be replaced by in-system and on-site processes, tailored to specific circumstances and requirements. It could even lead to the elimination of the distinction between water distribution and sewage systems as it becomes possible to combine them without impacting on public health. And thirdly, in the field of nanotechnology, advances are likely to have the greatest impact on maintaining and enhancing the performance of infrastructure. This could come about through the use of sensors, smart materials and materials with the ability to self-heal and regenerate.

3. The outlook for infrastructure investment requirements

This section provides an overview of the projections presented in each sectoral chapter and gives a brief outline of the basis on which they were made. To begin with, however, a few cautionary remarks are in order. It is important to note that the purpose of long-term projections is not to forecast the future. Rather, it is to explore how the future might evolve given a set of economic, social, technical and political assumptions, among these usually the absence of any new policy actions. Despite the uncertainties naturally attached to such long-range projections, experience has shown that they offer a useful framework for identifying critical factors and for reflecting on the policy levers that could be used to steer the economy and society at large towards a more desirable future. Moreover, consideration of the major shaping factors can also help governments identify some of the policy levers that could be applied in pursuing objectives. With this in mind, the findings of the sectoral chapters should be treated solely as indicative of the order of magnitude of the investments that are expected to be required.

Telecommunications

Annual total infrastructure spending worldwide is expected to rise from USD 650 billion in 2005 to USD 745 billion in 2010, falling thereafter to USD 646 billion in 2015, USD 572 billion in 2020 and USD 171 billion by 2025. After a period of rapid expansion of capacity (notably in developing countries) in the initial phase, the sharp reduction towards the end of the period is due, according to the authors of the sectoral chapter, to a steep drop in technology and equipment costs and in new-build investment, as saturation in user populations is reached and the vast bulk of spending concentrates on renewals and support maintenance. Indeed, maintenance and renewal spend is assumed to represent by far the largest share (about 80% in 2010 and over 90% in 2020) of annual infrastructure expenditures. The major part of future infrastructure will be in the form of fibre optics and, even more importantly, radio access networks. The largest proportion of infrastructure investment will be devoted to multiple forms of mobile packet radio. Fixed line will act as complementary long distance and feeder access network.

Future infrastructure demand is likely to be determined by the increasing economic power of the developing world and by its populations' needs for accessibility – 3.5 billion potential users beyond the 2 billion or so current users of telecommunications in all forms. Although over the 25-year period OECD countries are likely to account cumulatively for more than half of all global telecom infrastructure investment, spending on infrastructure investment in non-OECD countries is likely to overtake that in OECD countries sometime towards 2020. In consequence, the developing countries and their requirements will begin increasingly to shape future telecommunications infrastructures, and future infrastructure technology could well leapfrog current OECD progress. The architecture of telecommunications infrastructure will move to simpler, less smart networks, with intelligence based at the edges in servers and new devices.

Electricity generation and networks

Large amounts of investment will be needed in the coming decades to meet the increase in demand for both the quantity and quality of electricity services, as well as to maintain and replace existing infrastructures that will be retired. In a reference scenario, in which no new government policies are assumed, total annual worldwide electricity investment needs through to 2030 average around USD 350 billion. More than half of this investment (about 53%) will go to transmission and distribution, with the latter claiming

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the lion's share of overall network investment. Although the bulk of the spending will be in developing countries (notably in China), new investment in Europe and North America will be substantial, so that OECD countries will nonetheless account for over 40% of worldwide investment in the electricity sector (and around 35% of transmission and distribution). Refurbishment of transmission and distribution infrastructure, including replacement of cables, substations and control centres, will account for well over half of total network investment worldwide.

In an alternative policy scenario, which considers the impact of new government policies to curb demand growth and promote switching to cleaner fuels (including more use of renewables and distributed energy), world electricity demand and investment needs grow less rapidly in almost every region, on average 15% less over the 25-year period. The main uncertainties surrounding the adequacy of electricity investment worldwide relate to the impact of market reforms, environmental constraints and access to capital. In general, the effects of market reforms and environmental constraints are most uncertain in OECD countries. Policy makers are seeking to address concerns about the adequacy and timeliness of investments to ensure system reliability and an adequate quality of service by establishing a market framework that sends efficient market signals to investors.

Land transport

Two modes of surface transport are addressed, road and rail.

Road transport: The report estimates new infrastructure construction (*i.e.* net additions and maintenance/replacement) over the period 2000 to 2030 at between USD 220 billion and USD 290 billion per year. The largest component of the road infrastructure requirement arises from the need to maintain, upgrade and replace existing road assets, which deteriorate over time. A smaller component actually goes to augment the road capital asset value. These estimates are broadly in line with previous albeit shorter-term projections (*e.g.* World Bank). Roughly two-thirds of all new infrastructure construction is expected to take place in OECD countries, and about one-fifth in the Big 5 economies.

Rail transport: Infrastructure requirements (new construction) of between USD 50 billion and USD 60 billion per year are projected over the period 2005-30. These are substantially higher than previous studies suggested, in part because they reflect some significant rail upgrading plans envisioned and commenced under the EU TEN-T programme and major rail-building plans (including high-speed rail) in China and other Big 5 economies. Again, some two-thirds of the rail infrastructure construction over the forecast period is expected to occur in OECD countries, followed by the Big 5 countries; the latter will account for around one-quarter of total investments.

There is some scope for deliberate government policy to influence modal use – and shift more road use to rail – through the diversion of up to 10% of new road construction (*i.e.* USD 20 billion to USD 30 billion per year) to rail (in addition to the levels of investment already forecast). These could have some attendant (though probably bearable) consequences in terms of deteriorating overall road infrastructure quality and rising road congestion. Also, road and rail connectivity to airports and ports is critical to growing international movements, and there is a risk in many cities for local planning and amenity issues to override national and international interests in improving these connections.

Water supplies and treatment

The projections for annual investment in water systems through to 2025 point to significantly higher levels of investment requirements than previous studies suggest. In the OECD and Big 5 economies annual expenditures in the range of USD 770 billion are projected up to 2015 and over USD 1 trillion by 2025. Much of this spending in Europe and North America will be on maintenance, repair and replacement rather than on additions to existing networks, since water systems in many of these countries are now very old and in poor condition. It is primarily in the developing world that new construction and expansion of networks will be required: in Africa only some 40% of the population are served with adequate water supplies, and only 80% in Latin America, the Caribbean, Asia and the Pacific. Not least in OECD countries, environmental pressures will continue to grow, as will the expectations of the general public with respect to environmental protection and natural resource management. These factors are expected to add significantly to the costs incurred in the supply of water services and wastewater treatment.

The projections indicate that as we progress through the next three decades, water-related infrastructure investment requirements are likely to grow significantly and could well dwarf the requirements in the other three sectors under investigation by 2020-30. This suggests that governments will need to pay particular attention to water in the future – not only because, like air or food, it is essential for life, but also because investment outlays will be huge throughout the world.

Total investment across all infrastructures

On the basis of the estimates provided in each of the sectoral chapters, it is possible to provide an overview of the findings on likely global infrastructure investment requirements through to 2030. These are presented in tabular form below. However, it is important to bear in mind not only the caveats spelled out at the beginning of this section, but also the fact that the projections for each sector have been developed on the basis of different approaches, different methodologies and different data sets. Hence, the table

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can only provide an indication of the orders of magnitude of the infrastructure investment requirements worldwide over the next few decades. Moreover, the figures reflect needs, which for many different reasons may not necessarily translate into effective demand.

Table 1.1. **Estimated average annual world infrastructure expenditure (additions and renewal) for selected sectors, 2000-30, in USD Bn and as a percentage of world GDP**

Type of infrastructure	2000-10	Approximate % of world GDP	2010-20	Approximate % of world GDP	2020-30	Approximate % of world GDP
Road	220	0.38	245	0.32	292	0.29
Rail	49	0.09	54	0.07	58	0.06
Telecoms[1]	654	1.14	646	0.85	171	0.17
Electricity[2]	127	0.22	180	0.24	241	0.24
Water[1, 3]	576	1.01	772	1.01	1 037	1.03

1. Estimates apply to the years 2005, 2015 and 2025.
2. Transmission and distribution only.
3. Only OECD countries, Russia, China, India and Brazil are considered here.

In addition to highlighting the importance of telecoms and water infrastructure investment requirements, the table gives some idea of the relative weight of infrastructure spending within the economy. Annual investment in the five sectors taken together is likely to account on average for about 2.5% of world GDP. If electricity generation and other energy-related infrastructure investments (oil, gas, coal) are included, the share rises to around 3.5%. An equally rough calculation suggests that for the period through to 2030, total cumulative infrastructure requirements in the above sectors amount to about USD 53 trillion. Adding in electricity generation would lift the figure to around USD 65 trillion, and other energy-related infrastructure investments to about USD 71 trillion. Clearly, the figure would rise further if one were to include other infrastructures not covered by this project, *e.g.* ports, airports, storage facilities.

Over the time scale considered here, it can be seen that investment in land transport and telecommunications is likely to decline, whereas that in electricity and water looks set to remain steady or increase slightly. The expected fall in telecoms infrastructure spending results not only from the assumed progress in technology but also from the main focus of the analysis on telephony.

Contrasting challenges in OECD countries and non-OECD countries

OECD countries already have much of their infrastructure stock in place. Nonetheless, over the next two or three decades they will require very significant amounts of investment in all the sectors covered here. These requirements stem to an important degree from the need to replace and maintain existing networks.

But these also have to be upgraded and modernised as demands on the quality of infrastructure and related services rise. In a rapidly globalising economy, it will prove essential for OECD countries and regions to strengthen their competitiveness by using modern, efficient infrastructure to attract technology, mobile capital, skills and knowledge. With mounting costs – *inter alia* from environmental regulations, rising urban land prices and the increasing complexity of projects, as well as from growing pressures on public finances – there will need to be changes in the ways that many infrastructures are organised and financed.

At the same time, a rising share of world infrastructure investment will be conducted in the developing world, notably in the Big 5 economies. However – except perhaps in the case of telecoms, and in countries with traditionally high rates of saving – it is not clear whether developing countries in general will be in a position to mobilise effectively the enormous resources that will be needed to carry out the necessary investments, unless far-reaching reforms are undertaken to improve the governance of infrastructure development and management, as well as the efficiency of these countries' financial markets. If they fail to do so, such countries could experience major disruptions of service with significant adverse effects on their economies, leading to economic slowdown or even stagnation.

4. Interdependencies and synergies among infrastructures

As becomes increasingly clear from the analysis conducted above, developments in one infrastructure sector can have important implications for developments in another. These may be complementary effects, as in the case with the application of satellite and other remote sensing technologies to increasingly sophisticated road pricing or metering of electricity and water consumption. Another example is the role that transport infrastructures have historically played in providing right of way for communication networks. The effect may on the other hand be substitutive, as with the use of telework and teleshopping, although to date the overall impact appears to be relatively limited. The incidence on other infrastructures however may in fact be of a different nature, creating for example situations of close dependency which in times of technical breakdown, natural disaster or malicious attack may lead to cascading disruption of critical infrastructures. Finally, the complexity of dealing with several different infrastructures at once may be an important cost factor. Road construction works for example increasingly have to cross or handle other surface transport modes as well as pipelines for district heating, natural gas supplies, electricity cables and drainage systems. Indeed, the cost of managing such interaction with other types of infrastructure may well prove increasingly burdensome in the future, unless appropriate solutions can be found (*e.g.* the application of GIS technologies).

In addition to the direct interdependencies described above, there are indirect interdependencies which result from the impact of infrastructure on patterns of human settlements. For instance, the automobile has historically favoured a more dispersed habitat, which has a bearing on the requirement for, say, water or electricity distribution. These indirect effects are particularly important for the longer-term perspective.

Table 1.2 presents examples of such interdependencies and synergies among different infrastructures in a simple, illustrative matrix.

5. Cross-cutting issues and policy challenges

The previous sections have considered the benefits that infrastructures can generate, explored how requirements for infrastructure services may evolve over the next thirty years or so, examined some of the main factors and uncertainties that may affect these projections, and identified some of the key interdependencies among the various infrastructures. It seems appropriate at this juncture to take stock of several of the broader cross-cutting issues and policy challenges that emerge from the discussion.

The challenges arise first of all from the fact that demand patterns for infrastructure services will change between and across countries as well as within countries. At the same time, the nature of infrastructure is likely to change as technology and user requirements evolve. Finally, financing the maintenance of existing infrastructure and deploying new ones, as well as managing change in an holistic manner across separate albeit interrelated facilities, will raise challenges of their own.

Challenges relating to the changing geography of infrastructure

The growing internationalisation of the economy and its impact on infrastructures

Globalisation impacts on infrastructures in different ways. As the economy's engagement in international trade and services increases, so does the need to ensure that transport, energy, water and telecommunications have the capacity to absorb intensifying levels of economic activity. Congestion problems may become particularly acute at a country's entry and exit points (ports, airports, frontier road crossings) and on the transport corridors leading to them. This is currently the case in parts of North America, Europe and Asia, as many economies struggle to cope with the surge in business generated by China's rapid growth. Similarly, the demands of an expanding world economy on supplies of electricity are straining many OECD countries' networks, making it vital to ensure that power transmission across frontiers is able to smooth out fluctuations in demand and make up for lost supply capacity in the event of disruption. And as markets grow, the search for economies of scale and scope accelerates and supply chains become increasingly global and sophisticated, notably as the volume of

Table 1.2. **Illustrative matrix of interdependencies among infrastructures**

Infrastructure	Telecommunications	Electricity	Land transport	Water
Telecommunications		Intelligent electricity networks, including remote metering (better demand management). Greater efficiency in spot and futures markets for electricity. More dispersed electricity consumption patterns.	Telework, teleshopping, videoconferencing, telemedicine – leads in some cases to reduced commuting and other travel. More effective vehicle fleet management. Intelligent highway systems – greater security, less congestion, more sophisticated road network pricing. Faster emergency response to accidents. JIT management and longer supply chains – generating more traffic.	With ICT and sensors – better monitoring and control of pollutants, degraded drainage systems etc., and potential for remote metering (better demand management). Possibly greater vulnerability of installations, requiring back-up and fail-safe mechanisms.
Electricity	Dependence on electricity, vulnerable to outages and voltage fluctuation. Electricity network can be used for transmission of information.		Source of power for trains. Progress in battery technology – greater use of electric and hybrid cars – may mean more charging stations. Wider coverage of household electricity – more dispersed habitat – more travel. Cost factor where road construction crosses underground electricity cables.	Dependence of water and wastewater systems on electricity, vulnerable to power failures. Hydropower plants. More widespread pumping and high-energy treatment of wastewater. Cross-subsidisation between electricity and water – depletion of aquifers and other natural water resources.
Land transport	Increases demand for mobile communications, location-based services, navigation systems, emergency services. May stimulate demand for video conferences. Provides telecoms with right of way to lay communications cable.	Use of trains to transport fuel for energy generation (coal, oil). Modal split in favour of rail results in net increase in use of electricity (consequences for sustainability objectives).		Impact on water infrastructure since this is often built alongside or under major highways. Where transport improves accessibility, new settlements will increase demand for water services. In emergencies, drinking water can be transported to disaster-affected locations.
Water	Extension of water infrastructure to new locations and new housing engenders increased demand for telecommunications.	Extension of water infrastructure to new locations and new housing engenders increased demand for electricity services. Use of waste for energy generation. Required to cool nuclear power plants.	Waterways as alternative to road and rail. Poor water infrastructure poses risks to road and rail infrastructures though flooding, pipe breakages, etc. Cost factor where road construction crosses drainage/water pipes.	

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intra-industry and intra-firm trade expands. Large conglomerates – international as well as national – are emerging in the domains of highway and rail construction, power generation and distribution, and water supplies.

The upshot is that in the next decades the role of infrastructures in underpinning the international economy is set to grow further. This will inevitably turn the spotlight onto the importance of transnational networks and of communications and power links that secure the gateways to global markets. Equally, it will raise all kinds of issues around the need to balance international objectives (*e.g.* the expansion of ports, airports and cross-border transmission lines) with national and local interests, the protection of citizens' rights and so on, as well as underlining the need for well-functioning frameworks for international competition.

Urbanisation and new urban forms

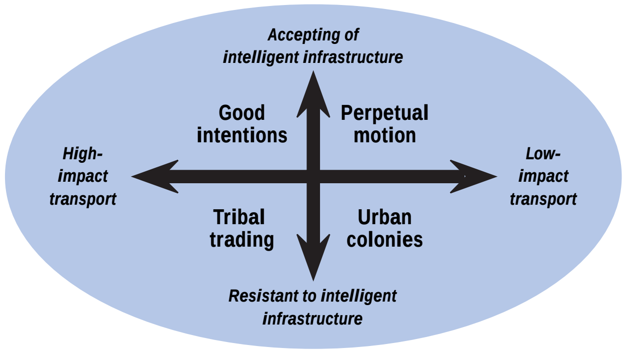
The ongoing overall trend in OECD countries' populations is still a slow but steady incremental increase in urbanisation. However, several emerging patterns might affect this process in the medium term, both quantitatively and qualitatively, and ultimately have an impact on infrastructure needs.

One such trend is the notion of "super-urban sprawl" described as the Telecomia by Bohlin *et al.* After the surge towards suburbia, there is now a movement of populations in OECD countries towards new profiles of residential properties such as low-cost villages and small towns with good amenities or remote large properties in open countryside. This pattern is creating needs for infrastructure (both *in situ* and networked) and for local services, but it is not likely to have a major impact in the short or medium term because of the dis-utilities and opportunity costs associated with it.

Telecomia should not be confused with other population shifts such as the movement towards coastal areas – be they in sunbelt, resort or high-tech cluster locations. This trend is driven by high-tech workers' preferences but also by retirees and telecommuters, who create real needs for additional capacity in infrastructure. Although these needs often occur in high-density areas they are sometimes very costly to satisfy (for instance water in California or European countries because of distant sources, or acceptance of waste disposal plants in the neighbourhood and right of way in the case of power transmission).

In the context of cities, four original scenarios towards 2055 were presented by the UK Foresight Directorate as part of the Intelligent Infrastructure Futures project. Although intended to cover the UK situation, the analysis is based on 60 trends and key drivers that are "universal" at least in the case of OECD countries, and therefore they are not only driven by ICT prospects. The discussion of potential impacts and issues here is limited to the 2025 timeline and the principal scenario.

Figure 1.1. **The axes of uncertainty and the four scenarios defined by combinations of those axes**



Source: DTI Foresight Intelligent Infrastructure Futures, The Scenarios – Towards 2055, Scenarios overview, p. 8 (2006).

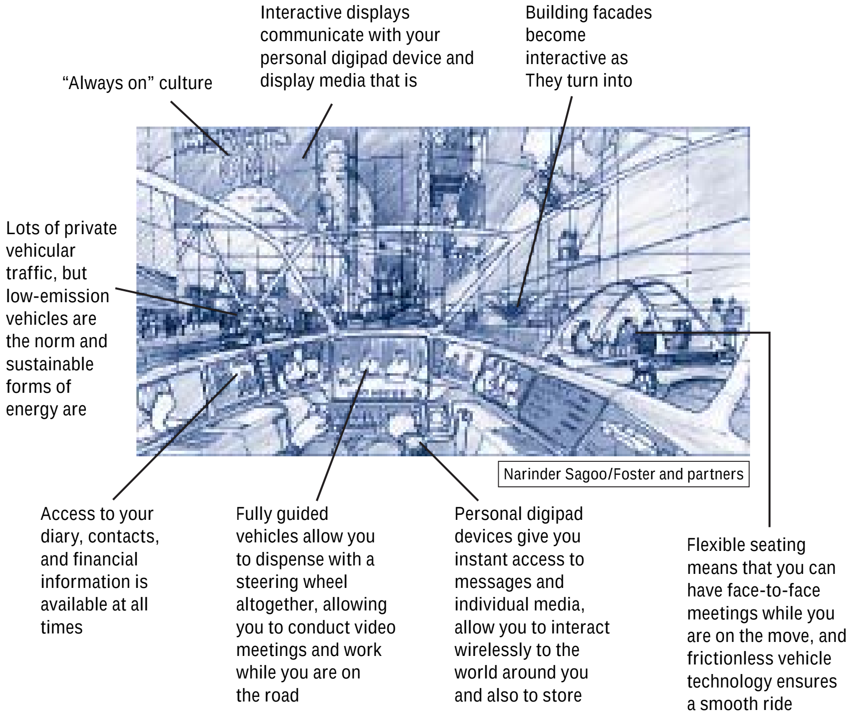
The two axes behind the four scenarios are based on two major uncertainties: whether or not environmental issues will impact the design of urban infrastructure (high or low impact axis) and whether or not people will accept intelligent infrastructure. As a result the four scenarios are coined "good intentions" or "perpetual motion" when intelligent infrastructure are accepted and "tribal trading" and "urban colonies" when there is strong resistance to them.

The "perpetual motion" scenario which is the "hyper" one in this context (but not necessarily desirable or plausible) describes a society where people are "always on", meaning that the norm is constant information, consumption and competition. Continued globalisation, economic growth and demand for travel are on the rise. New cleaner fuel technologies, including nuclear capacity and renewable sources, have reduced dependency on oil. Automated highway systems and on-board driver assistance are largely in use by 2025 as well as all the instant communication devices and services. Workloads are high and stress is a growing problem.

As recognised by the authors, this scenario represents the dominant discourse in western culture and assumes that constraints can be overcome by technology and innovation. It is the favourite scenario for the designers, suppliers and operators of intelligent infrastructure goods and services. As can be expected, this kind of scenario is "resource intensive" in financial and human capital, pace of innovation, raw and new material and social acceptance of risks and breach in privacy, potential losses of societal cohesion.

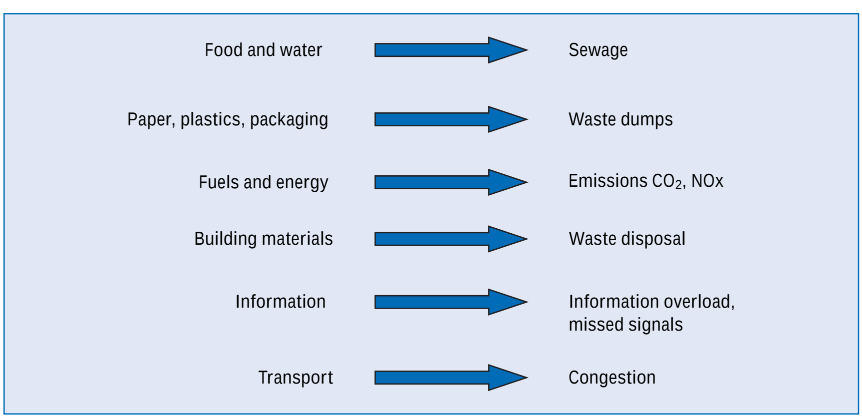
In a way, "perpetual motion" is also best illustrated or at least compatible with a linear infrastructure concept of urban development, shown below, in which cities are built as input-output models, taking all kind of resources from the environment at large and expelling all sort of wastes as a result of the process.

Figure 1.2. **The "perpetual motion" scenario**



Source: DTI Foresight Intelligent Infrastructure Futures, The Scenarios – Towards 2055, Scenarios overview, p. 10 (2006).

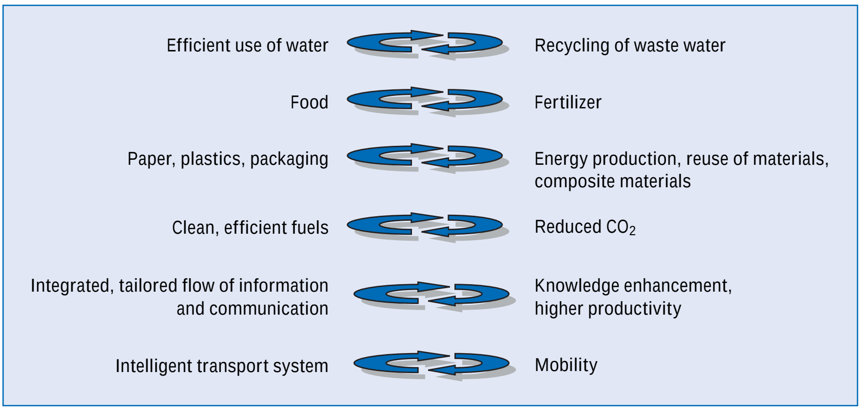
Figure 1.3. **Linear infrastructure**



Source: Adapted from Girardet, H. (1992), *The Gaia Atlas of Cities, New Directions for Sustainable Urban Living*, London: Gaia Books Limited.

As discussed in the previous sections on small-scale and distributed systems, a more organic concept of urban infrastructure can be imagined which would rely much more on closed loop processes. In this case of more sustainable infrastructure, the advantages of high-density patterns and economies of scale could be combined with more eco-efficient modes of production, consumption and transport.

Figure 1.4. **Sustainable urban infrastructure**



Source: Adapted from Girardet, H. (1992), *The Gaia Atlas of Cities, New Directions for Sustainable Urban Living*, London: Gaia Books Limited.

The two models would require significant investments in R&D, strong political will and social acceptance. The second would require more commitment and continuity since it would imply more institutional and organisational changes from the standpoint of many stakeholders and incumbents. As stated elsewhere in this publication and in the literature, big emerging markets would in principle have more leeway to choose the second route because of less legacy constraints, but it would require strong direction nonetheless.

In all cases, policies will matter. Among the many policy issues that would need to be addressed, three stand out as particularly challenging: the willingness to curb individual mobility rights; the level of internalisation of costs expected from operators and end users; and the level of polarisation acceptable to society.

Challenges related to the changing nature of infrastructure

Convergence, security and reliability of supply

A key question relates to the convergence that seems to characterise the future evolution of the four infrastructure sectors under consideration and its possible consequences. Such convergence is reflected first of all in the *growing* *interdependence* across infrastructure, in the sense that the service provided by one infrastructure is becoming an increasingly important input in the operation of other infrastructures. This is illustrated, for instance, by the greater reliance on telecoms expected in the future for the management of electricity transmission and distribution, as well as for land transport. But, as discussed earlier, the dependence also runs the other way, for instance the effective operation of the telecom infrastructure depends on the quality of the power provided by the electricity network. Similarly, failure of the electricity network can have dire consequences for the management of water facilities, and so on.

Convergence is also reflected in the existence of *economies of scope* in the provision of infrastructure services, *i.e.* the fact that as technology evolves, it may become more efficient to produce jointly several infrastructure services. Within the telecoms sector, this evolution is illustrated by the growing popularity of "triple play" offers, where the operator provides at the same time telephony, Internet and access to broadcast services. In the future, the importance of economies of scope in the provision of infrastructure services may increase, leading for instance to the possible merger between the telecommunications network and the electricity network for long distance transmission as well as the distribution of electricity and telecommunications services in the local loop. Another example is water utilities, which may assume a growing role in the production of electricity.

Convergence may have important consequences for the state of competition in the provision of infrastructure services, as well for the pricing of individual services. For instance, in the case of telecoms, providers of triple play may offer telephony for "free" since the marginal cost for them of providing the service (VoIP) is close to zero. As well, one may conceive of water treatment operators, eager to get hold of waste for producing electricity, offering sewage services at a discount to their customers, or electricity utilities offering free telecom services. The consequences for industry structure could be profound.

While such interaction across infrastructures may generate synergies, it is also a source of additional vulnerability: failure in one infrastructure may have serious domino effects on the others. It is unsurprising therefore that this growing interdependence of critical infrastructures is gaining attention in discussions of safety, security, and reliability of supply.

Large scale versus *small scale*

Another trend that seems to emerge from the analysis is a movement away from the large monolithic infrastructures of the past in favour of greater reliance on local autonomy, self-reliance and mobility. Clearly, in many cases economies of scale will ensure the persistence of large-scale installations. But equally, a trend toward smaller, more distributed systems can be observed. This trend is driven in part by technology, in part by deregulation and liberalisation, in part by security concerns, in part by environmental considerations, and in part by the difficulties governments have in raising capital for large infrastructure development projects.

Examples abound. In telecommunications, ATW (alternative wireless technology) local loops are emerging for health services and care of the elderly. These systems can be financed, built and operated by the local municipality (or private local operators) without the intervention of large operators. On the downside, the spread of such local systems might eventually put considerable strain on the frequency spectrum. In the case of water, a number of drivers such as environmental pressures (drought, floods, pollution), security concerns and mounting operating costs will create opportunities for recycling water and creating local loops. This model is likely to apply primarily to the urban and rural residential users as well as to industry. In the near term, developed countries could be the main users because the upfront investment will be borne by the end user and they need to have access to sophisticated technologies such as biotechnologies. As was seen in the case of recent privatisations, such moves may well create liability issues and the need to adapt regulatory oversight mechanisms.

In the case of energy, the diversification of sources is already high on some countries' national policy agenda. Distributed generation technologies may offer a number of advantages. For example, they tend to reduce the need for investment in long distance high-tension transmission lines. In the case of land transportation, by contrast, there is no obvious link to smaller-scale operations, although it has been noted that ageing populations in developed countries might create slower growth in vehicle ownership rates, little or no growth in km per vehicle and declining rates of road capital stock. But they could also create more needs for specific services such as minibus taxis and small buses. The increasing shift from taxes to "user fees" could also lead to reduced appetite for mobility, but the jury is still out on this issue.

An indirect impact of the emergence of smaller-scale systems may be to modify the industrial structure of the supply side. Instead of large systems built by the large engineering companies of this world (such as ABB, Alstom, Areva, GE, Siemens, Westinghouse in the case of energy) a share of the market might be supplied by a different breed of suppliers having more to do with high tech appliances, mass market and retailing capacities than with engineering-type operations. This in turn is likely to require norms, certification processes, and regulatory oversight in order both to protect the consumers and to make sure the potential risks are understood and efficiently allocated.

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A further indirect consequence of more widespread decentralised systems could be to shift funding needs from large operators to the end users or local suppliers. One result could be that investment volumes become atomised and handled on a day-to-day basis by a myriad of financial operators. Hence, business might move away from the structured financing departments of banks towards credit retailing departments (in the case of residential users) or leasing departments. The end result could be to reduce the overall burden of financing infrastructure by dividing the risks and spreading the transaction costs.

From the standpoint of efficiency gains, productivity and overall life cycle costs, it is too early to assume that cost/benefit analysis would militate in favour of decentralised systems as is often advocated by interest groups and non-governmental organisations (Gulli, 2006). Indeed, there is strong evidence that concentration is increasing within several sectors (telecom, road transport, electricity). Moreover, if economies of scope are significant as suggested in previous section, concentration across sectors is likely to increase as well. However, underlying trends and pressures are undoubtedly creating room for smaller-scale systems. It is impossible at this stage to predict which share of the market will see demand peak, or when. In this field policy matters, and incentives are already in place in some OECD countries – *e.g.* for windmills and use of local biofuels – that could accelerate uptake.

The rise of intelligent infrastructures

Whether centralised or distributed, in all four sectors, emerging technological capabilities are creating room for intelligent infrastructure. As in the case of other markets, the potential for intelligent infrastructure is not mainly technology driven (existing technologies in the 60s could have already augmented significantly the efficiency of some infrastructure). Other socioeconomic pressures, such as costs, environmental or safety/security concerns and public acceptance of risks, are much more likely to provide the impetus. A system perspective is therefore more appropriate as an analytical tool. Material in this section is based on the contributions from authors but also from members of the Steering Group of the project and particularly from the DTI Foresight Project: Intelligent Infrastructure Futures (2006).

In the electricity sector, decision support models and automation can create opportunities for optimisation of generation capacity, transmission lines and the grid. Distribution losses could be reduced, peak consumption better handled, reliability enhanced and environment better protected. The electricity sector is already one of the biggest users of ICT but this will imply an even greater deployment of ICT and software, and of sensors, remote sensing capabilities and interoperable components.

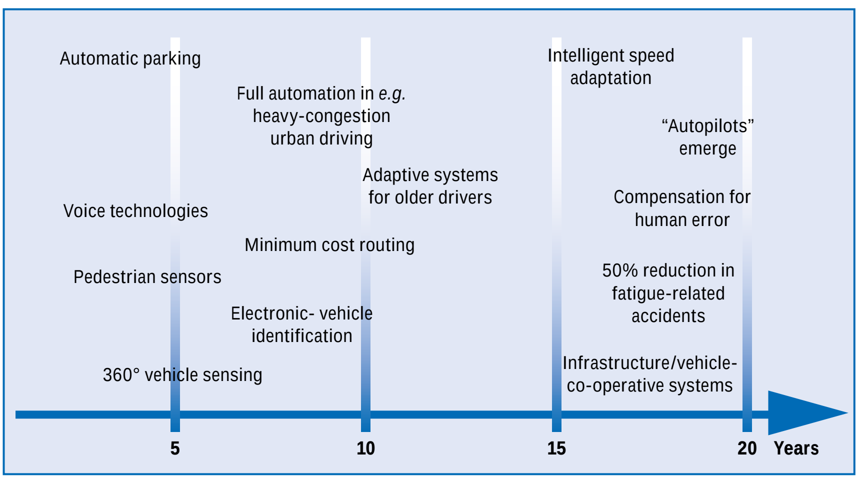
In the water sector, intelligent system modelling technologies can provide a greater ability to monitor and control in real time the water cycle. At local level or end user level, the virtual closing of the water cycle can also be monitored with sensors, embedded software and artificial intelligence.

In telecommunication systems, the integration of multiple AWT into a single multi-service platform can lead to a highly simplified infrastructure including self-healing and perhaps also self-organising networks.

Such integration will for instance in turn facilitate the creation of integrated health care systems, or "smart house" concepts for the elderly.

In the land transportation area, intelligent highways systems and advanced vehicle technologies could bring substantial benefits to network management, accident response, driver information and road/rail capacity (see Figure 1.5).

Figure 1.5. **Foresight vehicle technology roadmap: main capabilities identified**



Source: DTI Foresight Intelligent Infrastructure Futures, Technology Forward Look, Part 2, p. 11 (2006).

Intelligent infrastructure deployment has the potential to augment the capacity at a more or less constant level of fixed capital stock: for example, Stambrook mentions that safety and security enhancements on roads/rail can imply an additional upfront cost of 5%, but savings on maintenance cost could be 5% per year, so a high return on incremental investment can be expected. Intelligent infrastructure can also create substitution effects, but it is not clear to what extent.

Other potential benefits are difficult to quantify but could be very significant: enhanced safety of systems could be key in the sustainability of infrastructure although they create a new frontier: increased dependency on automated systems poses new serious risks such as system design failures, software unreliability or vulnerability to malevolent behavior.

The demand for telecommunication backbone, location-based services, navigation systems, emergency services and software engineering would increase. In addition, the points of application would change in the following way:

- Centralised systems (decision support models, command and control systems, nodes and networks) will be needed, but will quite often be in the hands of private operators or public agencies.
- *In situ*, on-board systems: railways and cars but also airplanes or ships will have more and more on-board systems and terminals; end users and local operators in the case of energy, water and telecommunications will have more and more *in situ* "autonomous" systems.

A significant transfer of upfront investments and risks could occur as an unintended consequence of this architecture. For instance, the most "visible" part of signalling and control systems (traffic lights, speed limit signals) would migrate from the roads and railway tracks to be installed on board, while sensors on the ground and in the air would create the missing links with the "overarching" system. Users of cars, trucks, *in situ* generation systems and operators of trains, trucks, airplanes, etc. would then bear more of the costs of capital, maintenance and risks which were in the past borne by the "owner" of fixed capital assets.

Inevitably, such changes will be accompanied by a swath of issues that will need to be addressed by policy – the setting of standards, questions pertaining to intellectual property, implications for privacy, and the role that government could play in R&D efforts, notably in areas that have strong public-good features.

Challenges raised by the future development of infrastructure

Meeting future financial needs

Beyond these general remarks regarding the evolution of infrastructure, three more specific observations are worth making with respect to investment needs and whether they are likely to be fulfilled. First, it is clear that the investments that will be needed in the coming decades are very large indeed across sectors, in part because a significant share of this infrastructure has suffered from benign neglect in the past (for instance water infrastructure), in part because of the large transformation expected in developing countries in the future (growth in population, growth in per capita income, rapid urbanisation), and in part because of the new demands that will be put on such infrastructure for security reasons and in response to growing concerns about the environment.

The second observation is that, especially in OECD countries, public funds are very likely to come under considerable pressure in the next few decades as the demands of ageing populations on health, pensions and social services begin to take their toll and governments face shrinking tax revenues. This suggests that public authorities will need to be more innovative in moving away from taxes to other forms of revenue raising for infrastructures (*e.g.* user charges), but also in helping to shape the respective roles that the public and private sectors can play in financing, building and managing infrastructure.

The third observation is that – perhaps with the exception of the telecommunications sector – none of the other sectors has put in place an institutional framework that is up to the challenges of the future, including a regulatory framework that allows for the full and effective participation of private actors.

The pricing of infrastructure services

In a market economy, pricing plays a key role in maintaining a balance between infrastructure supply and demand, in providing guidance for investment decisions and in fostering efficiency. The role of prices has increased over the years in sectors that have moved from a command and control mode of regulation to a "regulated competition" regime. This is the case for network pricing in the telecoms sector and to a lesser degree for the electricity sector. On the other hand, the role of prices remains limited in the water sector and only marginal in the land transport sector.

In the telecom sector, competition is expected to foster the deployment of new technology and to drive cost and prices down to "near-zero" levels, creating thereby the conditions for the rapid expansion of telecoms in the developing world (Bohlin *et al.*). However, this will depend on how fast prices will converge towards costs, and notably on the evolution of the price of basic carriage, which in turn will depend on how such infrastructure will be regulated. Given the enormous capacity of optic fibres and the high cost of deploying them, economies of scale in basic carriage are likely to be very large indeed, resulting in a high degree of concentration. In this context it will be important for regulators to ensure that access to the infrastructure remains open and that access charges reflect costs.

The price of electricity plays a key role also in adjusting supply and demand in the short term (*e.g.* role of peak-load pricing). Electricity prices moreover have an impact on fuel choice. For instance, the widespread introduction of time-of-day electricity pricing at wholesale level that fully reflects the higher cost of generating power at peak would improve the competitiveness of gas against coal. Electricity pricing is also a key factor for investment decisions. For instance, low transmission rates have contributed to insufficient levels of transmission investment in the United States as well as in

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a number of European countries according to the US National Energy Policy Development Group (United States, 2001, p. 115). Despite the liberalisation of the sector, owners of transmission facilities (who continue to operate on a monopoly basis) often have little incentive to invest in new facilities. This is because current regulatory frameworks do not provide a mechanism for transmission owners to share the benefits that accrue to power plant owners and electricity customers from competition, even though transmission lines are what make the competition possible (APERC, 2003, p. 23).

If investments in transmission and distribution are to have a reasonable prospect of being profitable, they must be able to earn a return in excess of the weighted market cost of capital. Thus, in setting transmission and distribution rates, energy regulators should allow a regulated rate of return that at least equals the weighted cost of debt and equity in the marketplace (APERC, 2003, p. 23). Setting such rates at the proper level is particularly important in a liberalised environment to the extent that liberalised electricity markets are likely to require increased levels of investment in transmission to accommodate greater volumes of electricity trade. Moreover, investment in efficient transmission and distribution reduces losses and can be an effective way to lower costs to consumers as well as to reduce emissions of power generation-related pollutants.

In the water sector, pricing has been notoriously inadequate to ensure the necessary investment in infrastructure. The significant underinvestment that has prevailed for decades in some countries is a growing source of concern not only for the water utilities but also for the health authorities. Replacing or refurbishing transmission and distribution mains is critical to providing safe drinking water. Failures in transmission and distribution lines can interrupt the delivery of water and possibly allow back-siphonage of contaminated water. Distribution mains in poor repair can pose acute health risks by providing an environment in which bacteria will grow. Moreover, use of pesticides and fertilisers is also likely to lead to further deterioration of water quality and thus to rising costs.

This is clearly an unsustainable situation that calls for a substantial reform of the regulatory regime that governs the sector. In developed countries, a major effort to upgrade infrastructure over the next few decades is inevitable. In developing countries, the major new infrastructure needs resulting from population growth and urbanisation can only be accommodated if an appropriate pricing scheme is put in place. This will be a challenging task given the need of ensuring, at the same time, that the poor have adequate access to the water they need. This may call for the introduction of pricing schemes where the price per unit of water consumed increases with usage, so as to allow vital uses (*e.g.* drinking water) to be met at minimum cost to the user, while discouraging at the same time wastage and heavy use.

In contrast to the previous sectors, pricing plays only a limited role in land transport. In this regard, Stamford notes that unfortunately (for land transport authorities), the concept that there should be a "price" for public capital access and that such revenue should remain within the land transport sector appears to be rejected (or overridden) by other public finance "principles" and spending priorities. However, in this sector also, the gradual introduction of pricing appears both desirable and inevitable, although the main intent may not be the financing of capacity extension but rather attempts to moderate demand growth.

Meeting the environmental challenge

Environment policy is expected by all authors to be an important factor influencing the development of infrastructure in the coming decades, but its impact is hard to ascertain since it will very much depend on how strong political will to make the necessary reforms is likely to be, what measures will be implemented in practice, and what their impact and effectiveness will be.

As noted earlier, governments are likely to encourage the development of telecommunications as a way to reduce the need for land transport (although the evidence on this score is rather inconclusive to date) and make traffic flow more efficiently, thereby reducing the need to build new infrastructure. Telecommunications will also be used to improve the operation of other infrastructure. This includes for instance more intelligent electric networks capable of responding more flexibly to changing demand patterns, and more effective monitoring of water networks so as to reduce leakages and hence the need for water withdrawal.

Governments may also impose additional charges on some infrastructure so as to curb demand or introduce resource-saving measures. For instance, future demand for electricity could be moderated by taxes that increase the cost of electricity for final users, as well as by measures to promote energy efficiency (standards, labelling, building codes).

Higher electricity prices will be needed to cover the additional costs imposed by environmental policies for the generation, transmission and distribution of electricity. Regarding generation, environmental costs may account for 10% to 40% of total plant costs in fossil-fuel plants and more in nuclear plants according to the IEA. Transmission costs are also likely to rise because of the need to reduce emissions of SF6 (used in transformers and other equipment), which contribute to global warming, and the impact of electromagnetic fields around cables.

Environmental policy is also likely to pay particular attention to water utilities. Indeed, water is integrally linked to the health of the environment. Water is vital to the survival of ecosystems and the plants and animals that live in them; in turn, ecosystems help to regulate the quantity and quality of

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water. Hence, environmentalists will put growing pressures on the water sector to close the water cycle, *i.e.* to ensure that used water is fully recycled. This could add considerably to the cost borne by water utilities, a cost that should logically be reflected in higher water prices.

In any case, higher water prices are likely to be increasingly considered as desirable *per se* by environmentalists, if only because of the substantial environmental benefit they can bring about, simply by curbing the demand for water. Indeed, simulation results suggest that higher water prices induce a dramatic reduction in the ratio of withdrawals to total water availability and a significant improvement in water quality as the re-use of water declines, and the reduction in water withdrawals provides a major increase in environmental flows (Rosengrant *et al.*, 2002, p. 153).

Environmental policy will also affect the demand for land transport. This includes for instance sustainability-inspired measures to shift traffic from road to rail for urban and inter-city use, although Stambrook does emphasise here the limited margin of manoeuvre available.

The creation of markets for carbon emission permit trading will also have a bearing on future infrastructure development, notably in the energy sector. A case in point is the European Union Emissions Trading Scheme (ETS) established in January 2005, which affects the activities of 13 000 factories and power stations in five different industries in Europe. Up to now, there is no sign that the permit regime has brought about a switch to cleaner fuels; indeed the reverse has been happening. Part of the reason is that gas has become so much more expensive than coal that power stations have chosen to pay higher permit prices and switched to coal; moreover, it seems that too many permits have been issued. Another factor is the uncertainty that exists regarding the future evolution of the market. However, these teething problems are likely to be ironed out in the future and the use of carbon trading extended to other sectors of the economy. This could have major implications for energy use in the future (*The Economist*, May 6, 2006).

The challenge of managing future change

Balancing infrastructure policy objectives

Public policy plays a key role in shaping infrastructure investment decision for all four types of infrastructures. However, it is highly unpredictable. One can only speculate on the direction it might take in the coming decades and its possible impact on infrastructure requirements.

Regarding telecom, Bohlin *et al.* note that liberalisation and democratisation have had an enormous impact in the past on the ownership, structuring and operation of telecom networks, on the quality and reliability of service, on the nature and range of the offerings, and on accessibility. In many countries, the move has been away from a command and control model or monopoly incumbent to a more competitive environment, including separation of service from infrastructure and the opening of infrastructure to competition. In the future, harmonisation of infrastructure standards globally will be essential, including an opening up of the radio spectrum towards more unlicensed bands and the weakening of national regulators in favour of regional regulators, with global co-ordination becoming more important. Given the convergence of content and carriage, such international co-ordination/regulation should logically extend eventually to content. However, this is likely to raise serious sovereignty issues. At the local level, the use of AWT is likely to increase, driven by municipalities. However, incumbents are expected to continue to fight a rearguard action to protect their sunk costs in existing infrastructure against the price onslaught of VoIP. It will be up to the regulators to ensure that the entry of new players is not unduly constrained by such delaying tactics, that a healthy state of competition prevails in the industry, and that new technology is used to its full potential for the benefit of consumers. However, main players should not be discouraged from investing in new technologies. This means that regulators will need to strike a fine balance between maintaining an open environment and stimulating innovation by incumbents and challengers alike. Whether they will be able to do so effectively remains an open question.

Liberalisation and unbundling (*i.e.* separation of power generation, transmission, distribution and supply) has also had a major impact on the energy sector. However, the outcome is more mixed than in the case of telecoms: while such reform may have led to efficiency gains it is also creating a more uncertain environment for infrastructure investment decisions, and raises questions regarding the appropriate level of capacity reserve. Hence there is a danger that not enough investment will be carried out in the future unless more effective risk management techniques are put in place. Alternatively, governments may have to step in or allow a partial reconsolidation of the industry, which may raise important competition issues as noted by Morgan in the IEA chapter.

Public policy plays also a dominant role for land infrastructure. Indeed, because of the overwhelming presence of the state in the sector, land transport investment may well fall victim of the "short-termism" that characterises the public decision-making process, according to Stambrook. Land transport infrastructure (road and rail) has a very long economic life (30+ years) – and capital planning and budgeting requires a lengthy (10-20 year) cycle that clearly conflicts with 7-year business cycles, 3-5 year political cycles and 2-3 year budgetary cycles. Any time there is a short-term crisis, long-term plans for land transport infrastructure funding will be sacrificed for short-term expediency to meet other, more pressing political pressures and policy agenda goals.

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Stambrook points out also that, even if new construction is economically desirable, public finance policy and constraints may not allow the "wealth/ output-maximising" level of road new construction to occur. Several of the political/finance factors that might be limiting include: degree of political stability, degree of public corruption, lack of public revenue raising capacity, tax avoidance, high inflation, etc. One (albeit contentious) solution to the problem could perhaps be to move responsibility for land transport infrastructure away from the political arena to an arm's-length regulatory agency (as is already the case for telecom and energy) and to allocate at least a share of the tax revenues generated by the use of land vehicles to land infrastructure investment.

Public policy plays also a central role in the management of water resources. It is a particularly complex task as it involves a broad range of public and private stakeholders at the international, national and local levels with disparate and sometimes conflicting interests. In this complex institutional context, the state of the water infrastructure is largely determined by the way lines of responsibility and financing are established, by how conflicts between the different stakeholders are resolved, by what overall government policy objectives are established and by how such objectives are pursued. In developed and developing countries alike, a major challenge for the future will be to make the institutional changes required to modernise and strengthen the legal, policy and administrative arrangements that govern the sector, so as to balance effectively the interests of users, give due consideration to health and environmental concerns and ensure at the same time that the sector is put on a secure financial footing. This is no easy task.

As Ashley and Cashman note, there is a growing need for effective regulatory oversight, no matter how services are provided, and a need for central government to continue to play a strategic role, especially with respect to social, environmental and fiscal policy direction. The potential challenges for regulation are likely to increase as new technology is adopted and organisational forms respond to its deployment. It could well be that responsibilities in the area of service delivery become blurred, requiring a greater level of governance to protect the public. The interrelationship of different spheres of regulation, safety, economic, quality, environment, consumer protection and perhaps others will become more challenging and complex. Moreover, the private sector's participation in water services will inevitably grow – not necessarily as a result of privatisation, as there is only weak evidence that privatisation does actually result in greater investment in water services. Decentralisation and more effective private sector involvement are seen to be the way forward through various forms of outsourcing as service providers seek to improve efficiencies and adopt technological innovations.

Adapting to the changing institutional context

These reforms will have to take place in a changing institutional context where in many parts of the world the responsibilities of the nation state are being "hollowed out" upward, *i.e.* where greater oversight responsibility is assumed at the supranational level. This is because states have increasingly sought to establish international mechanisms to facilitate and mediate their relationships as such inter-state relationships have become more complex. In this context, supranational bodies, such as the EU and WTO, will become increasingly important with respect to policy issues and the terms of engagement. For example, the EU plays a particularly important role in the European water sector, as it is instrumental in setting standards and requirements that have a significant impact on water services and infrastructure.

The "hollowing out" of the nation state is also taking place downward, as responsibility for a range of infrastructure service functions are devolved away from central government either to local or regional bodies, or delegated to state or non-state agencies. Making the right decisions in this increasingly complex institutional environment will become ever more challenging.

Improving the policy toolbox

Finally, an important aspect to emerge from the sectoral chapters is the need to improve the tools at policy makers' disposal. Among the items addressed in these chapters are the quantitative and qualitative inadequacy of the infrastructure-related statistics and data sets currently available; the utilisation of more sophisticated cost/benefit analysis, notably methods that include consideration of indirect effects of infrastructure development and not just the direct effects; more widespread use of accrual accounting for infrastructure cost, depreciation expense and financing costs; and the potential of network-wide asset planning and project identification as well as comprehensive asset management and performance measures.

6. The road ahead

The economic, demographic, political and technological changes that the next two to three decades are set to bring will have significant implications for infrastructures. It seems very likely that the changes will necessitate a thorough review of the strategic objectives, financing mechanisms, risk- and burden-sharing (both among stakeholders and across society), management methods, planning procedures and operating modes currently in place – in short, a re-examination of the prevailing infrastructure business models and their long-term viability. Needless to say, that viability is inextricably intertwined with the policy environment and the governance context in which infrastructures are developed. The next stage of this Project will therefore focus on the likely evolution of the business models prevailing today, the pressures for adaptation, the potential for innovation, and the kind of policy frameworks that will need to be implemented if infrastructures are to play in full the role required of them in supporting and enhancing economic and social development worldwide.

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Infrastructure to 2030
Telecom, Land Transport, Water and Electricity

Chapter 2

Telecoms Infrastructure to 2030

by

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Executive summary

Over the past 35 years investment in modern telecommunications infrastructure in the OECD area has generated significant economic growth. It has widened access for consumers and business to communications of all kinds while making significant reductions in transaction costs.[1] This is as true for the infrastructure provided by the Internet as for the successors to the public switched voice telephony, including the now disappearing fax, the current mobile and SMS services and the arrival of future lifestyle services over a broadband connection. The importance of telecommunications is reflected in its growing share of world output. The OECD notes that investment was 2.9% of gross fixed capital formation averaged over 2001-03.[2] Other sources cite an increasing investment over the past 25 years, from 1.6% of an estimated USD 20 trillion in 1975 to 2.9% of an estimated USD 40 trillion global GDP in 2000.[3]

Telecommunications penetration was historically low in a number of OECD countries. In 1970, France, Portugal and Italy for example had only 8, 6, and 12 fixed telephone phones per 100 inhabitants respectively, while only the United States and Canada had near-universal service.[4] In 1995, just under half of the membership of the International Telecommunication Union (ITU), comprising 214 countries, had telecoms penetration rates below 8 per 100 inhabitants, the level attained by France in 1970. For this reason the spread of mobile, which globally now exceeds the number of fixed users, is increasingly important.

Future infrastructure demand is likely to be determined by the increasing economic power of the developing world. By 2025, the economies of Brazil, Russia, India and China (BRICs) could account for over half the size of the G6.[5] Currently they are worth less than 15%. The shift in GDP relative to the G6 will take place steadily during the 21st century but is likely to be most dramatic up to 2030. Even so, individuals in the BRICs are still likely to be poorer on average than individuals in the G6 economies.

The accessibility of mobile over other technologies will be the main driver of its future success in those countries. The demographic trend towards an aged population will seed the need for richer services to support people and their health and to provide care for the elderly in most of the world. Emergencies, both manmade and natural, will demand new requirements from telecommunications infrastructures.

Infrastructure will be shaped and driven by the needs for accessibility for the large mass of the unserved world – 3.5 billion potential users beyond the 2 billion or so current users of telecommunications in all forms. In consequence, after 2010 or 2025, the developing countries and their requirements will begin to shape future telecommunications infrastructures. Future infrastructure technology will leapfrog current OECD progress. Tomorrow's infrastructure will demand a much lower spend than today's fixed line and cellular mobile and will be much quicker to roll out.

The major part of future infrastructure will be devoted to transport of IP packets, carried by fibre optics and largely by radio access networks by 2030. In terms of infrastructure investment, the largest proportion will be devoted to multiple forms of mobile packet radio. This will fit with the needs of the largest client for new infrastructure, the developing world. Fixed line, for both packet and circuit switched communications, will act as a complementary backhaul long distance and feeder access network.

OECD countries are only likely to turn to the technical and cost advantages of the new lightweight infrastructure at a later stage. The model of higher access replacing low access technologies has a parallel in the history of transport from canals to private road transport. Thus fixed line backhaul infrastructure will tend to remain static in topology and geographic link structure, but will expand in link capacity by replacement of signalling technology – so the same fibre optic physical link will carry more traffic.

The architecture of telecommunications infrastructure will move to simpler less intelligent networks, with intelligence based at the edges, in servers and user devices. The predominating form of switching will be packet switching tailored for isochronous communications. The infrastructure will need to contain security verification of sources and addresses, as well as monitors for spam and for identifying capturing and captured user nodes ("zombies" and "botnets"). New protocols based on IPv6 will expand the address space in response to the needs for far more users, past the 4 billion addresses of IPv4 by many orders of magnitude.

Telecommunications infrastructure competition will continue in the early part of development to 2030. Fixed infrastructure operators will attempt to rival the mobile operators with converged (fixed and mobile) services. Cable operators and Internet Service Providers (ISP) will increasingly enter telecommunications with either a fibre network for backhaul or a service offering acting as a VIP, with use of unbundled capacity. Business models of the operators are likely to change as a result of price competition and lower costs of entry, so the service competition from new players such as ISPs, media and cable companies will be important.

Often overestimated in the past, telecommunications will nevertheless increasingly be viewed as a potential substitute for travel. This could reduce dependencies on vehicles and their fuels and ameliorate the effects of pollution. The potential impacts of teleworking, teleshopping, distance learning and e-commerce are such that the distribution of habitat and supply chains for retail could be affected. This will have fallout effects on other infrastructure services, notably electrical distribution, gas for heating, sewage and water supplies, as more remote regions become effectively closer to work with the death of distance from work. However, as previously noted, telecommunications also stimulates the economy and produces additional travel and other energy use. For this reason, telecommunications substitution effects will always be less than imagined.

Introduction – the scope of the study

Our study sets out to examine telecommunications as an infrastructure element, its development to 2030 and its impact on other elements such as transport and energy. It begins by establishing the scope of the study at two levels – in terms of the relevant telecommunications sub-sectors for infrastructure and also the geographic focus of the analysis.

Among the many potential telecommunications sub-sectors, the study focuses on the three that are likely to be most important for the future:

- Fixed line telephony and data – the main infrastructure component today.
- Mobile telephony and data – including alternative wireless technologies beyond cellular mobile.
- Broadband mobile communications, especially wireless broadband.

Other technologies may only be touched on in passing, including satellite communications, microwave links, HALES (high altitude long endurance systems) and cable TV, except as a support for multi-service broadband and as backhaul for mobile radio systems.

Geographically, the study will examine infrastructures in specific economies:

- The OECD community.
- Several members of the "Big 5" newly industrialising countries, specifically China, India and Brazil.

Sectoral scope

Fixed line telephony and data

Developments and modernisation. Over the past 130 years, since the inception of the Bell System in the United States in 1875, the main infrastructure stock in telecommunications has traditionally been in fixed line technologies, originally analogue voice telephony. This consisted of three major elements, the local loop, the switches and a trunk or long distance network.[6]

Digitalisation of the infrastructure. Renewal of the technology stock largely over the period 1973-2000, led by OECD countries, moved the infrastructure of much of the world from analogue signalling and control to digital switching and transmission. The benefits of digitalisation included expanded line capacity with advanced multiplexing, a higher complexity of switching, improved speed of call set up end-to-end, and above all far higher network reliability. A richer set of features could also be added via programmability to customer premises equipment and to the network elements. The process of digitalising all telecommunication networks is nearing completion across the OECD area, with the majority of the OECD countries being 100% digital in 1999. In those countries the proportion of fixed lines connected to a digital exchange is 99% in 2005, but Hungary (88%), Spain (90%) and Turkey (90%) are among those whose networks lag the OECD average.[7] In the developing world we see a quite different picture. As telecommunications infrastructure spend took off so late (in the 1990s), much of the equipment was digital to begin with. Thus, India and China exhibit the latest in digital switching, alongside a much earlier generation of analogue equipment, especially in India, and to some extent in Brazil.

Future of the fixed network. Many incumbent operators are facing a reduced number of fixed line subscribers as customers give up second lines or migrate completely to mobile networks. As a result of this process and competition from mobile services which have a much higher penetration than fixed networks, the incumbents are losing voice revenues. This revenue loss is augmented by developments in VoIP markets. Profitable fixed line voice margins are thus tending to reduce under the pressures of mobile infrastructure competition, the challenge of VoIP and regulation to open up the local loop, so that unbundling can take place, with service providers competing in the local loop.

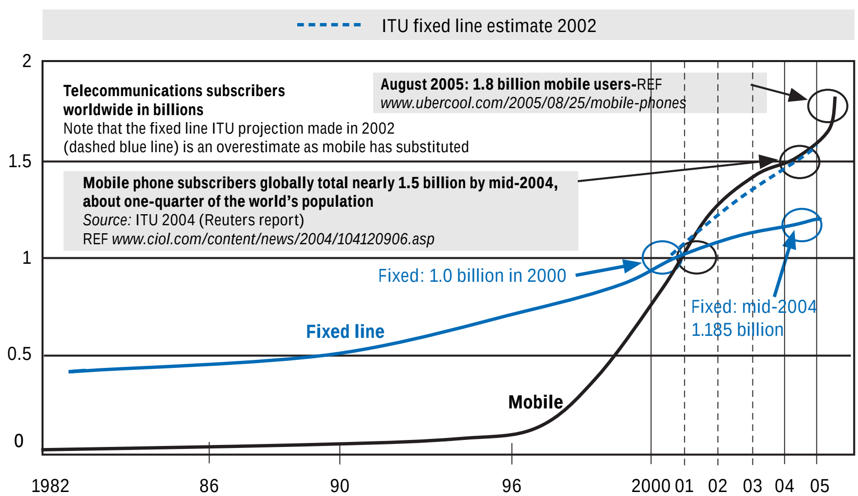
In response, incumbent operators of fixed networks are considering "converged" architectures for "co-opetition" with mobile and VoIP. An example is BT's 21st Century Network (21CN) architecture designed to provide both mobile connection and fixed line to and within the home ("bluephone") and office. It employs a trunk network designed to be the interconnect and backhaul transport for mobile traffic for other carriers on a wholesale basis. Thus fixed-to-mobile "convergence" is changing the fixed infrastructure architecture for all large fixed line operators.

Mobile telephony and data, including alternative wireless technologies

Mobile is now the most important growth sector in telecommunications. It represents over half of new global telecommunications expenditure on infrastructure today and its users have overtaken fixed line users in total numbers from 2001 onwards, as shown below. Nearly all mobile and wireless networks are now digital although there is still a small but rapidly decreasing share of analogue services in Mexico and the United States. Nearly a third of the world's population owned a mobile phone by end-2005; only 23% owned a fixed line.[8]

What the fixed network achieved in 130 years was matched by mobile in about ten:

Figure 2.1. **Telecommunications subscribers worldwide**

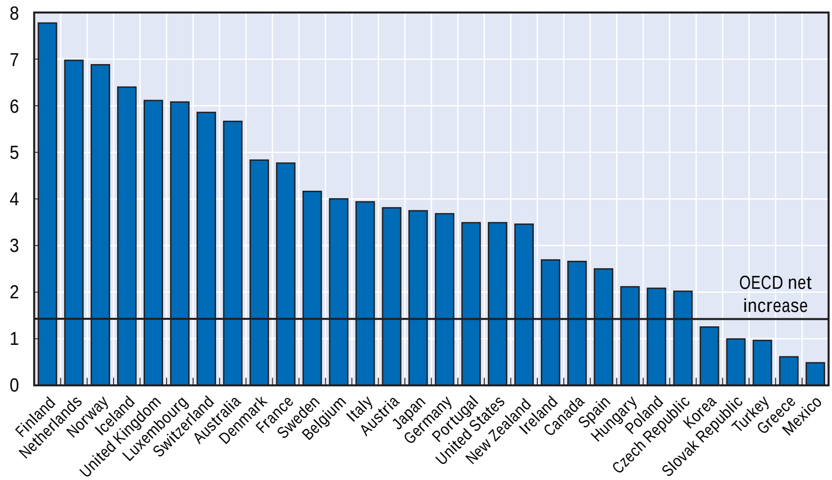


Source: ITU WORLD Telecommunication Development Report, 2002; ITU World Telecommunication Indicators Database and IUT Projections.

Broadband mobile communications, especially wireless broadband

The rollout of broadband, in the range of over 100 kbps up to 2 Mbps, has accelerated over the past five years. Originally oversold in a technology "push", demand has at last arrived through customer need for faster Internet access. In the OECD community it has largely been sold via variations of DSL (digital subscriber line) technology and cable television (CATV). Other broadband technologies in use include satellite broadband for Internet access, fibre-to-the-home (FTTH) and to the curb (FTTC), Ethernet LANs, and fixed wireless subscribers (at downstream speeds greater than 256 kbps). The latest development is in wireless broadband access for fixed usage, which is developing into mobile and nomadic extensions with technology such as WiFi and WiMax. The following graph and table show OECD broadband penetration figures per 100 inhabitants and growth by country.

Figure 2.2. **OECD broadband penetration (per 100 inhabitants) net increase Q2 2004-Q2 2005, by country**



Source: OECD.

Traditional wired broadband infrastructure is being driven by alternative wireless technologies, such as WiBro from South Korea but especially WiFi hubs for Internet access at hotspots for nomadic users.

Geographic scope

OECD

Traditionally the OECD community has been the builder and leader in telecommunications infrastructures. It has set the model for others to follow since 1875. In many OECD countries there is overcapacity in long distance fibre that is still not economic in terms of revenues for payback of original investments, but just how much is very difficult to judge as unlit fibre may not be declared. Moreover, much international transoceanic capacity was sold after the dotcom bubble burst and that in Asia was bought by China and India and other developing countries. With regard to the remaining capacity in the OECD area, the increase in traffic has supported increased investment in the Internet backbone networks. Despite competition, both at the service level and infrastructure level, prices are thus being kept artificially high in some domains (and not just fixed communications, *e.g.* in mobile termination, international and off-same-operator mobile roaming charges, etc.). However,

Table 2.1. **OECD broadband subscribers per 100 inhabitants, by technology, June 2005**

	DSL	Cable	Other	Total
Korea	13.9	8.9	2.7	25.5
Netherlands	13.6	8.9	0.0	22.5
Denmark	13.2	6.1	2.4	21.8
Iceland	21.0	0.3	0.4	21.7
Switzerland	12.7	7.2	0.4	20.3
Canada	9.4	9.7	0.1	19.2
Finland	16.3	2.2	0.2	18.7
Belgium	11.0	7.3	0.0	18.2
Norway	14.8	2.5	0.9	18.2
Sweden	11.3	2.7	2.5	16.5
Japan	11.0	2.4	3.0	16.4
United States	5.5	8.0	1.1	14.5
United Kingdom	9.7	3.8	0.0	13.5
France	11.9	0.8	0.0	12.8
Austria	7.0	5.4	0.1	12.5
Luxembourg	10.4	1.3	0.0	11.8
Australia	8.5	2.4	0.1	10.9
Germany	9.9	0.3	0.1	10.2
Italy	9.4	0.0	0.6	10.0
Portugal	5.1	4.7	0.0	9.9
Spain	7.0	2.2	0.1	9.3
New Zealand	6.4	0.3	0.3	6.9
Hungary	2.9	1.6	0.1	4.6
Ireland	3.5	0.4	0.5	4.3
Poland	2.5	0.7	0.1	3.3
Czech Republic	1.8	1.0	0.0	2.8
Slovak Republic	1.2	0.3	0.1	1.6
Turkey	1.1	0.0	0.0	1.2
Mexico	0.8	0.2	0.0	1.0
Greece	0.8	0.0	0.0	0.8
OECD	**7.2**	**3.8**	**0.8**	**11.8**

Source: OECD Web site, accessed January 2006:
www.oecd.org/document/16/0,2340,en2649_34225_35526608_1_1_1_1,00.html.

recently prices in fixed communications have begun to change rapidly as many operators now offer a fixed price unlimited call package. In the mobile market for termination fees, new dual-mode handsets (mobile/WiFi) should enter the market at the end of this 2005 (*e.g.* the Nokia N92 handset) which may put pressure on the roaming market in some OECD countries, depending on regulation.

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Table 2.2. **The global distribution of WIFI Hotspots – Commercial hotspots in 2004**[1]

United States	20 488
Korea	18 000
Italy	415
Sweden	435
Australia	539
Canada	572
Taiwan	643
Japan	1 022
Germany	1 167
France	1 676
United Kingdom	4 620
Total	**49 577**

1. François Bar, "Divergent patterns of global innovation: WiFi in the US", Annenberg School for Communication, University of Southern California, United States, presented at ENST, Paris, April 2004; and EC/IPTS study, "Mapping European Wireless Trends and Drivers", 2005, Case Study on Korea.

Table 2.3. **Telecom Diffusion within the OECD area population**

OECD 2003	2003								
Population (million) 1970	Population (million) 2004	Fixed lines (× 1 000)	Telephone density (per 100 population)	Mobile subscribers (× 1 000)	Mobile (per 100 population)	Mobiles as % of total telephone subscribers	Internet users (% of population)	Population (million) 2030
875[1]	1 153	503 435	43.67	741 343	64.2	59.6	22.4	1 275[1]

1. Population of current OECD members.

Source: US Census Bureau, OECD, International Telecommunication Union.

However, as will be shown below, this traditional position of the OECD area as a technology and deployment leader may now be challenged. Moreover, its advantages in an early technology lead could hold back certain OECD member states due to "intense political inertia" for protection of sunk investments in a fixed, low bandwidth, high-cost, circuit-switched, national infrastructure. Nor has this inertia disappeared with recent deregulation when considering the next generation of digital packet-based DSL lines. The United States, Japan, and now Germany (although now being questioned by the EC) are proposing protection from unbundling and sharing by incumbents of their new broadband fibre and xDSL local loop networks.[9] Such moves can exclude competitive access for service provision over the new investments, the professed aim being to encourage the large players to invest.

China

China was chosen as the most advanced of the largest developing economies. China is adding more than 3 million new wireless users a month, with a 4.8 million increase in users during August 2005. Spending on infrastructure is accelerating. Mobile subscriptions in August 2005 had risen in total to 373 million.[10]

Table 2.4. **Telecom Diffusion within China's population**

China	2004							
Population (million) 1970	Population (million) 2004	Fixed lines (× 1 000)	Telephone density (per 100 population)	Mobile subscribers (× 1 000)	Mobile (per 100 population)	Mobiles as % of total telephone subscribers	Internet users (% of population)	Population (million) 2030
820	1 313	312 443	23.79	334 824	25.49	51.7	7.2	1 462

Source: US Census Bureau, OECD, International Telecommunication Union.

India

India has been selected since significant acceleration in infrastructure investment is expected, as it probably has the largest telecommunications infrastructure gap worldwide, compared to potential demand. Its 1.1 billion population has average GDP per head of USD 640 and projected GDP growth of 7.5%.[11]

Table 2.5. **Telecom Diffusion within India's population**

India	2004							
Population (million) 1970	Population (million) 2004	Fixed lines (× 1 000)	Telephone density (per 100 population)	Mobile subscribers (× 1 000)	Mobile (per 100 population)	Mobiles as % of total telephone subscribers	Internet users (% of population)	Population (million) 2030
555	1 080	43 960	4.07	47 300	4.37	51.8	3.2	1 421

Source: US Census Bureau, OECD, International Telecommunication Union.

Mobile has a strong part to play in this – in June 2005 subscriptions had risen to 7.4 million,[12] which indicates how fast India's spending on infrastructure is accelerating. So far the country has based much of its growth in hi-tech services (such as business process outsourcing) on industrial parks with tied communications via satellites with VSAT dishes and some international fibre drops, in order to avoid the poor local infrastructure. Now this model of "enclave communications" is no longer good enough. An

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indigenous local communications infrastructure is increasingly required, not just as an international access infrastructure, but for communications to interwork within the local economy.

Brazil

Brazil was chosen as an interesting comparison, to understand how it may evolve, perhaps as China has done, and India may do. The economic base is far more advanced than China or India with GDP per head at USD 3 200 in 2005 and GDP in 2005 projected to be 3.5%,[13] an indication of how investment in infrastructure is building. Brazil has been developing only slowly owing to political and financial crises. Its population has doubled over the past 30 years although the average number of children per mother has reduced from its 1970 figure of 6 to about 2, so that modest prosperity is reaching more of the population. In this situation of disposable income, mobile penetration has reached over 35% of the population, far outstripping its fixed lines (under 25%). Deregulation has promoted strong mobile competition, not just between cellular operators but effectively in infrastructure competition.

Table 2.6. **Telecom Diffusion within Brazil's population**

Brazil	2004							
Population (million) 1970	Population (million) 2004	Fixed lines (× 1 000)	Telephone density (per 100 population)	Mobile subscribers (× 1 000)	Mobile (per 100 population)	Mobiles as % of total telephone subscribers	Internet users (% of population)	Population (million) 2030
96	181	42 382	23.46	65 605	36.32	60.8	12.2	223

Source: US Census Bureau, OECD, International Telecommunication Union.

1. Past trends in infrastructure investment

This section briefly reviews the telecommunication infrastructure developments of the past 25 years by examining four areas of trends in infrastructure investment:

- Past demand and the main drivers.
- Current state of the infrastructure.
- Whether past developments in demand will continue.
- Which trends seem clearly unsustainable.

Influence of the main drivers on past demand for infrastructure

Since 1980 there have been many attempts to develop and launch new infrastructure or services. Those that succeeded were responding to real, expressed or latent needs of users – the demand side of the economy. Others can be placed on a technocentric wish list from the industry, anxious to sell to the customer. The table below analyses some major launches from this point of view:

What we see here is the strong influence of the drivers on the demand side, especially the consumer segment, while business demand follows. Increasingly, the recent developments in infrastructure demand show that the main influence is no longer a decision by the operators/suppliers on what is to be provided; the

Table 2.7. **Impact of main drivers on past demand**

Infrastructure and infrastructure-related services development	Main drivers	Overall impact
Digitisation	Cost and performance through technology advance – responded to customer need for more reliability, network sophistication and services such as voice mail.	Fundamental – responded to need for reliable, sophisticated telecommunications integrating voice and data as one channel.
ISDN – Integrated services digital network, a digital circuit-switched voice/data protocol for the local loop, based on CCITT standards.	Technocentric push by suppliers and operators – but despite this some customer success in France and Germany especially in business markets, and in US T1 lines market. ISDN was sometimes translated as – "idiot services users don't need" – in UK and USA.	Minimal – for narrowband ISDN, except for certain business markets, especially the T1 leased line market in the 1990s.
Mobile – principally GSM, 2G and 2.5G (GPRS)	End user demand for access from anywhere, for ease of ubiquitous calling and specifically for personal security (linked to 50% of sales).	Fundamental – over one decade (1995-2005) mobile has created a whole new subscriber base, double that of fixed line and so revised over 100 years of infrastructure. It has also provided infrastructure competition to fixed line calling.
Broadband long distance backbone, national and international with SDH protocols over fibre networks with WDM	Cost and technical (ease of upgrading capacity) for growing international data traffic, especially Internet users after 1996/7 as World Wide Web interface made the Internet popular.	Major – reduced real costs of a voice call by several orders of magnitude (*cf.* transatlantic voice call cost of provision, 1946-2005[1]).
Broadband local loop technology largely over traditional (CCITT) tels networks (FTTH, FTTC, DSL and radio, mobile or fixed) but also CATV	Technocentric early drive (pre-2002) and so rollout exceeded demand; later, after 2004, end user demand for higher bandwidth access became real as Internet usage increased.	Slowly becoming more important.
WiFi, from non-operator – centric organisations (hotels, airports, municipalities, etc.) as well as traditional operators	Dual drivers – push from microprocessor supplier Intel to sell PCs –and demand for Internet access from nomadic users, especially for data transport and more recently for voice, with VoIP (Skype, Vonage).	Large, slowly becoming more important as WiFi hubs spread and VoIP becomes better in quality.

1. S. Forge, "The macroeconomic effects of near-zero tariff telecommunications", multi-client study, SCF Associates, Paris, 1998.

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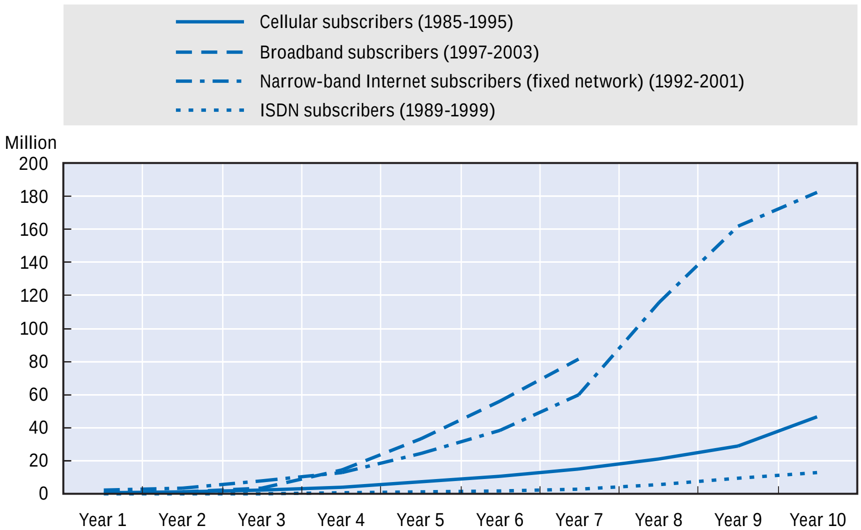
supply-side has declined in power. It is worth noting that in the OECD community, local loop broadband is now growing much faster than mobile did in its early days as shown in the figure below on the takeup of services.

Figure 2.3. **Broadband takeup over first 10 years is faster than previous services across the OECD**



Source: OECD, 2005.

The demand side focus is on ease of accessibility – as the move to digital mobile clearly demonstrates. Digital mobile based on the GSM standard was a far greater success than expected despite its creation through a regulated standard setting process for new digital mobile technology, rather than a competitive market in technologies. In contrast, various attempts at wideband/broadband rollout have floundered. The first attempt was through ISDN (Integrated Services Digital Network), in which the public switched telephone network (PSTN) local loop was to be replaced by wideband cabling (coaxial or fibre). More recently various DSL protocols[14] carried over hybrid fibre and coaxial cable (HFC), or the original twisted pair in some installations, have been used to upgrade existing local loops at much lower cost. But again, DSL broadband only took off when real demand appeared, for Internet access. This lack of real demand largely explains the failure of third generation (3G) mobile to take off. Not only have mobile operators been slow in rolling out the network but there have been problems in the availability and price of handsets, while the 3G market seems to have been picking up far more slowly than operators expected. The price of data access is one main inhibitor and the complexity of handsets and services, and *fears* about pricing are others.[15]

The major point here is that there is an underlying force behind the successful developments of recent times. Liberalisation has been a significant driver of infrastructure development over the past 25 years since it has allowed the door to open to a new era of *multiple* infrastructures. Demand-side forces, especially the power of consumers acting on the political balance in government, have produced a revolution in the three key infrastructure drivers of telecommunications:

- As noted, first and foremost is regulation, or rather deregulation. Liberalisation of the market allowed the power of incumbent operators to be restricted and the entry of new players, unleashing the following two factors.
- Competition of all kinds – in services and equipment, and significantly in infrastructure competition.
- New technology – whose introduction, up to deregulation, was entirely controlled by the incumbents.

The United States' Modified Final Judgement in 1983 under Judge Harold Greene and the break–up of the dominant operator and equipment provider, AT&T, heralded the end of an era and a move globally to a new liberalisation of services. Limited infrastructure competition had begun in the United States before the MFJ ruling using bypass technology for an alternative infrastructure for long distance – the microwave-towers of Microwave Communications Incorporated (MCI) from the mid-1970s, funded by the junk bond market.

Hence the 1980s opened telecommunications markets to competing service providers and, to a limited extent, competition in the local loop though unbundling and alternative infrastructures. In some US cities an alternative fibre network infrastructure was built in the 1980s in deregulated local markets – one of the first being Nebraska.[16] However, the promises of the US CLECs (competing local exchange carriers) in the early 1990s to provide services over the existing incumbent's infrastructure have yet to be met. The local RBOCs (Regional Bell Operating Companies, originally seven telcos created as a result of the break up of AT&T) have never really relinquished control of the local loop infrastructure in the United States and thus tied the customer to themselves. With enough power over the regulator (the FCC and the local Public Utility Commissions, PUCs) and state laws the incumbents slowed or halted effective local loop unbundling in that country. It is not surprising, therefore, that the long distance piece of the break-up, AT&T, could not survive as no customer ownership was effectively possible; it has recently been bought out by one of the descendants of the original RBOCs, SBC.

However, in the United Kingdom the recent Strategic Review by the regulator in the United Kingdom, OFCOM, has forced the incumbent, BT, to set up a separate operationally independent entity, Open Reach, with its own accounting as an alternative to hiving off the local loop infrastructure into a

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different corporate entity. It is intended that it resell unbundled local loop capacity to third parties on a level playing field with its parent, an arrangement that required careful negotiation. BT's infrastructure had been specifically designed from the late 1970s on to make separation of local loop and long distance parts quite difficult, especially when the business support services of billing and operational support services for network and service management are considered. Although the United Kingdom has gone furthest, most EU countries have some plan for unbundling the local loop. Effectively, all EU countries still require unbundling.[17]

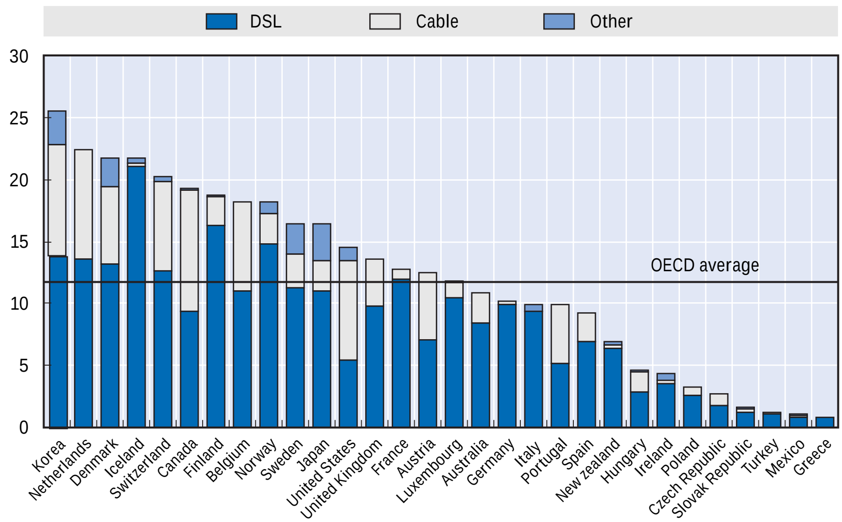
This regulatory sea change over the past 25 years has contrasted with the previous hundred years of voice telephony in that it reveals that the public demands for an infrastructure to better meet their needs were to some extent being heard by government and regulators. This is despite the fact that the public and business demands for better infrastructure at lower cost were not expressed in any way that was concrete or detailed. At best they were latent demands, a need for services that could correspond to requirements for data, mobility and flexibility in customer premises equipment. More deeply, this required release of the stranglehold of the incumbents over the way in which services were supplied, and their high costs, based on using the local loop infrastructure as the jugular vein through which to squeeze the customer.

The current state of the infrastructure

In OECD countries, households have a growing number of Internet connected PCs and so the local loop is increasingly based on some form of broadband connection. The fixed line infrastructure has been boosted by DSL for the local loop for voice, Internet access and television programming. In many OECD countries the cable TV operators or multi-service operators (MSOs) offer their own broadband coax or fibre connections for FTTH (fibre to the home) or FTTC (fibre to the curb with copper extensions). Thus, bandwidth is available in the local loop, at a price related to cost of deployment, and is adequate for most demands by domestic consumers for voice telephony and Internet access. Businesses are equally demanding of more bandwidth for their e-commerce and voice telephony needs. VoIP is beginning to take a small amount of voice traffic (usually under 5%) in certain OECD countries and most of all between them for international calls.[18] Local loop unbundling in the OECD has not only delivered on the promise of lower prices through competition in the retail market, but has resulted in new entrants providing increasingly higher speeds and bundled services including the provision of television programming on xDSL.

Business communications demand varies by country. In general, fibre capacity for long distance has expanded enormously, so that there is now a bandwidth glut due to overspend by the incumbent operators also challenged by new small entrants to the long distance market who targeted the wholesale ISP

Figure 2.4. **OECD broadband subscribers per 100 inhabitants, by technology, June 2005**



Source: OECD, OECD Web site: *www.oecd.org/dataoecd/60/47/35527500.xls*.

market and large business networks. New entrants such as COLT, Level 3 and Global Crossing expanded in an era of apparently unending infrastructure demand, financed in the dotcom boom and the corresponding telecoms boom by large bank borrowings. Discovering the true extent of the surplus is extremely difficult, as there is high interest in maintaining a silence over excess "dark" fibre. The situation is complicated by the lack of industry consensus on whether dark fibre should be measured as part of the total stock of available fibre – some have argued that because it still requires investment to light dark fibre it should be excluded from consideration of available capacity. However the costs in laying fibre may be one or two orders of magnitude greater than lighting it.

So just where are the gaps in today's infrastructure?

Turning first to the big growth sector, mobile, we see that the new 3G technology based on the 3GPP standards is currently not seeing the success expected in 1999 – a period of exuberant expectations – and so many operators are now relying on 3G technology upgrades. Back in 1999, the initial 3GPP standards were near completion and investments were amassed to buy licences in the first rounds in the United Kingdom and Germany in 2000. What has been delivered is a technology, not a service, with high cost and relatively low bandwidth (2 Mbps) and 3.5G upgrades to HSDPA (High speed downlink packet access) and HSUPA (High speed uplink packet access) being required for assured 2 Mbps working. Currently, Vodafone is growing at one million 3G customers per

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quarter; at that rate it would take over 40 years for Vodafone's global customer base of around 165 million customers to convert to 3G.[19] However, some note that it is possible to compare the situation with the early months of 900 Mhz GSM, when only business users were taking up the service so that the same conclusion with GSM *versus* analogue might have been reached, and also for 1 800 MHz PCS in 1994 against 900 Mhz GSM.

High on cost and low on appeal, 3G also has problems of universal reception and talk-time drop-out which can prejudice end-to-end packet networking. Thus many of the first 3G networks are still circuit switched, at least over the radio access network. The high cost of wideband and broadband 3G cellular mobile and the low bandwidth of the successful 2G and 2.5G mobile leaves a gap – for low cost high bandwidth mobile.

Another gap is in the increased need for emergency services that can operate anywhere during a disaster. Accessibility and resistance to catastrophes are driving needs for adaptive *ad hoc* networking with a mesh architecture.

Looking deeper into the network, we see that the local loop, access networks and trunk networks in many of today's OECD economies host a wide variety of circuit switched network elements, combined with various local loop and access-network packet switching technologies (frame relay, X25, ISDN E1 and T1, T3 and others, such as "Kilostream" and "Megastream", TCP/IP routers, etc.). Attached to this is a mix of higher speed ATM and SDH trunk networks, using SS7 inter-network signalling systems, with a wide variety of TMN (telecommunications management networks) and OSS (operational support systems). In consequence many of today's network architectures suffer from complexity and high cost of maintenance and repair. The gap to be filled is in providing a single model for access network and trunk network operation running a single protocol and with one form of switching. It should have the simplicity of the concepts of the Internet, based on data communications and its universality of protocols and addressing, but with enhanced security and robustness to deliberate attack, in comparison with an Internet designed for a trusting, naïve world.

Perhaps the largest unmet need is concerned with cost. The growth markets of the future will be outside the current OECD countries. China and India will form at least half the world's economy by 2025, while China will surpass Japan to become the world's second economy by 2020.[20] The gap in infrastructure is in meeting their needs – for fast rollout, low cost and high accessibility. The nature of this demand favours radio technologies, either still emerging or yet to be developed, with lower cost backhaul and trunk infrastructures. Today's infrastructures can only meet their needs with piecemeal solutions.

However, for the OECD community, there may be a difference in the type of growth. While the NICs extend their new technology infrastructures, on the OECD side there may be a capital deepening – putting in the new technologies, perhaps grown up in the NICs, to introduce new services and features. Such a next generation network (NGN) will change the nature and use of communications networks in the OECD countries (as noted earlier, to allow for telecommuting, e-commerce, etc.). This could be a quite different process, a progressive replacement, in contrast to the swift rollout of low cost networks in China which break new ground in the vast new markets of the infrastructure hungry NICs.

Will past developments in demand for infrastructure continue in the future?

With the growing importance of the knowledge-based economy, the demand for telecommunications and its infrastructure will continue to expand well beyond 2030. But what past developments will be continued to 2030? Three key demands can be identified that will continue to shape infrastructure spending.

At the forefront of the continued demands for telecommunications infrastructure development over the past two decades has been the expanding mobile radio services. However, whether the current cellular model will continue in its present form is open to question. It is possible that the setbacks with the 3GPP UMTS[21] model mean that cellular mobile has reached its limits, showing that the technology cannot be stretched further. New technologies, rather than extensions of current technologies, may be the answer. High accessibility will continue to be the lasting trend – the more ubiquitous and pervasive the access to communications, the surer it is to enter into general use. Access includes cost for many potential users, so a falling cost of infrastructure access per subscriber will be a key parameter, again continuing a past trend in telecommunications.

The second main development has been the general move to higher bandwidth, right down to the local loop for media services including Internet access. Here we can observe a move in demand away from the "plain vanilla voice" role of telecommunications into multimedia data. This is also likely to continue. Governments also realise that telecommunications (such as today's push for local access broadband) has important social and economic benefits. Broadband has been promulgated as the cornerstone of the digital economy and there has been recognition by many policy makers that without competitive provision of broadband access, price levels for access would remain high and the diffusion of broadband would remain low. The question is therefore how to implement it. The current infrastructure approach using fixed line, either hybrid fibre coax (HFC) or purely fibre optics, or possibly twisted pair over short distances, may be in doubt if lower-cost wireless technology can do the job, such as Korea's WiBro.

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The third development of the past few decades likely to continue is the fundamental enabler of telecommunications progress – the enhancement of competition in services, technologies and infrastructures, through the measures of liberalisation of telecommunications. Such deregulation will include the unbundling of tied assets where they present a restrictive practice, as well as the encouragement of alternative competing infrastructure technologies.

Which past trends seem to be unsustainable in the future?

Most important perhaps is a sustainable cost base of infrastructure for the future user population. The current level created in the OECD community sets today's baseline but it is too high for the segment of user population with the highest potential for future growth – the newly industrialising countries (NICs) – and so cannot be sustained.

One feature of the market over the past few decades has often been the technocentric push from major players such as operators and equipment suppliers, offering technologies from a supply-side position, not as consumable products and services. Although it is unlikely to disappear, the weight of consumer power is now realised and this phenomenon of supply-side dominance is probably unsustainable.

The above two points are, to a considerable extent, a consequence of control by dominant incumbent players, operators or suppliers. With increasing competition, this market power is unlikely to be sustainable, so that the role of the national incumbents is likely to diminish as new groupings form, often across national borders. The impact on infrastructure will be to increase competition between infrastructures, as cellular mobile, new mobile, Internet ISP bulk transport, cable TV, etc. expand the competitive scope.

Turning to network architectures, the past telecommunications industry view based on voice with circuit switching being extended for data is being swept aside by data-oriented architectures. Moreover, the mix of telecommunications standards from bodies such as the ITU and the CEPT, which has already diminished, is likely to become even less important. Data communications standards, from the Internet community and the computer industry bodies such as the United States' IEEE, are likely to underpin telecommunications infrastructures, with their focus on an open, unregulated market. A prime example is packet switching and specifically the new IPv6 protocol. Moreover, the Internet itself has certain unsustainable features, most specifically the underlying software it has grown up with, which assumes a benign world and so has significant security gaps; much will need to be replaced.

At a more general level, the dominant role of the original OECD community in leading and setting global telecommunications standards and originating technology is no longer sustainable. Global infrastructure standards and technology will increasingly appear from the NICs. Thus the traditional lead of the OECD may now be leapfrogged. Moreover, prior investments in traditional technology could hold back certain OECD member states, owing to the political inertia generated by protection of sunk investments in a fixed, low-bandwidth, high-cost, circuit-switched, national infrastructure.

2. Key factors driving future demand and infrastructure investment

In coming decades, the demand for infrastructure services will be largely determined by a number of major drivers of change, including trends in the following areas:

- geopolitics;
- security;
- macroeconomy;
- finance;
- demography;
- environment;
- technology;
- governance;
- telecommunications pricing;
- microeconomics – primary consumer basics inflation.

Geopolitics

Geopolitics – the way political power is exercised at a global level – has strong implications for telecommunications. Telecommunications itself is increasingly shaping the geopolitical scene, both through direct communications and its diversification into multimedia content, spreading culture, news and political views. Internet access effectively opens the door to new and sometimes contrasting views and cultures, for instance the role of women in society. Mobile communications allows no act to go unobserved. Events in China, the Ukraine, Georgia have been reported, or popular political movements have been co-ordinated, in opposition to official news communications, by using personal communications. Mobile introduces dialogue (via voice or SMS) to replace a state monologue. Thus the traditional role of telecommunications as a strategic asset and military asset in time of war has become a political asset for popular movements and is changing the political balance of governments. In some ways it hastens the decline of the nation state towards more complex social, business and organisational interactions. As democracy and telecommunications seem to be linked to economic progress, so their spread will tend to drive the economic rise of the NICs eventually to challenge the United States as the world's dominant economic power. By 2030 global capability will no longer just be a US prerogative, since China will also be present, as will the EU, to project their power abroad. Thus telecommunications infrastructure will be more transnational and global players will emerge as they are doing in mobile (*e.g.* Vodafone, Orange, Telefonica, Hutchison, etc.). Telecommunications internationally will continue to be the driver of outsourced job-migration or offshoring, with some five million jobs already exported to Asia from western OECD countries.[22] Offshoring will continue to be a driver of telecommunications. For military reasons such as terrorist threats, certain new telecommunications infrastructures of an *ad hoc* nature will be researched and put into service. Also, use of standard new safeguards and security abilities within the telecommunications infrastructures, such as forced legal interception and decoding of communications, will be introduced to networks worldwide.

Security

Fundamentalist politics, the migration of differing religious and ethnic groups, continued social inequalities and organised crime will drive international tensions through terrorist and criminal activities. Thus security issues will be to the fore. They are a main driver of telecommunications infrastructure design and specifically the next generation of alternative wireless technologies (AWTs), as evidenced for instance by the WARN (Wireless Accelerated Responder Network) system, a mobile broadband network for public safety covering security and emergency services in Washington DC, based on Flash-OFDM. Moreover, security of telecommunications with Internet access will become a paramount subject of economic threat as trade via the Web mounts and the scope of identity theft, electronic funds transfer theft and money laundering becomes an everyday issue for most people. If national and international e-commerce is to take off, the telecommunications infrastructure must have an underlying security architecture that assures not only secure operations but that the *privacy* of the individual is also respected.

Macroeconomy

At a macroeconomic level, the wealth of developing nations will tend to increase up to 2030. This is a fundamental driver for telecommunications and its infrastructure build. Increasing incomes will drive all forms of telecommunications takeup, most specifically mobile.

Mobile is the lead technology for reasons of access, in two forms, with the driving forces of access examined in detail in Section 4. For a mass market, the technology of mobile can be used to give ubiquitous access at far lower cost. Secondly by its nature, of radio propagation for the local loop, its speed of installation for national coverage is a few years, not a decade or more as it would have to be for a wired network, whose cost of deployment for local access would be many times higher, making standing charges unaffordable for most citizens. The importance of this for large sub-continent size countries such as India, Brazil, and China is enormous. In OECD countries, with a fixed infrastructure already in place, one likely scenario is that as fixed and mobile converge, the end user will not be able to differentiate as to how they are accessing networks or the path that their call/session is taking, However, ubiquitous accessibility is already making substitution of mobile for fixed attractive to active users, and according to ITU figures, fixed lines have slowed in rollout from the expected path (see ITU projections in Figure 2.1).

Moreover, a virtuous cycle is entered into, as telecommunications take-up drives the economy through better market information, which increases overall per capita income.[23] Income inequality has been growing but the numbers of those on under 2 USD per day income may well decrease faster than expected with good telecommunications. The main growth in telecommunications deployment and technology can be expected outside the developed group of nations, especially as the location of expanding economic activities moves to China, India and the developing world. It will be driven by private investment largely in competitive situations. The drives towards efficient sanitation, with clean drinking water for the poorest, will accelerate with telecommunications infrastructure. As the share of services as part of the developing economies rises, as opposed to manufacture, so the demand for telecommunications will strengthen. This is already evident in India, with export of its software services.

Public finance, investment and capital markets

The growth of telecommunications, and especially its infrastructure, is intimately linked with financial markets, because privatisation with deregulation has come to the fore in the telecommunications industry, so that the state is no longer the prime telecommunications investor. WorldCom (formerly MCI) in the United States (started to rival the AT&T monopoly in the 1970s) had to finance itself through effective founding of the “junk bond” market in the 1980s, as an alternative to direct bank lending. The telecommunications boom of the late 1990s and its collapse in 2000/01 put the US and global banking systems in peril due to the enormous amounts lent to operators (WorldCom, Level 3, etc.) to build fibre optic networks and to buy other telecommunications operators and Internet companies. One significant reason for the enormously high prices paid for the 3G licences in Europe was the willingness of the lender banks to provide the capital necessary (some EUR 100 billion) and their encouragement of the leading players, in whom they often held equity, to acquire a 3G licence. Thus the health of the lending markets (securities and banking) is crucial to telecommunications infrastructure expansion. However, the dependence of the past on massive capital spend (*e.g.* USD 1-2 billion per year for a large 3G mobile

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rollout over one or two years) may be likely to change. Certain new technologies demand far lower infrastructure investment and are more aligned with the local finances and inward foreign investment levels of the developing economies. However, some form of failure of the banking system is still possible in the situation of another global bubble in telecommunications.

Demography

As in all mass technology plays, population growth and changing age composition are crucial to industry behaviour going forward. Two main factors will drive infrastructure – the overall expansion in population numbers and the aging rate of these populations. Sustainable support for an aging population inside the OECD group (and increasingly in China and India) will demand new uses of telecommunications in elder care and medical health care. Urbanisation will also be a market driver. Moves to the city, especially in the countries with large demographic expansion and industrialisation, that is the developing nations, will drive demands for a new telecommunications infrastructure to serve the rising numbers of citizens. International migration from developing to developed countries will drive up population in the OECD community and so power its telecommunications infrastructure expansion. The numbers are significant – the migrant population in 2000 reached 13.5% of the world's population.[24]

Environment

Climate change is accelerating as energy consumption increases, in the EU at about 1.8% per year, expected to continue to 2035 with its concomitant pollutant affects as greenhouse gas emissions. The fastest increase is in Asia at 3% per annum – a 41% increase in emissions over the period 1973 to 2002 has already been seen.[25] North America is the largest energy consumer and polluter in 2005, but Asia is expected to be the largest energy consumer from 2010 on.[26] Climate change looks certain to increase sea levels with permanent loss of land, more floods, tidal waves and more hurricanes which will be more powerful due to average sea temperature rise and sea current changes, such as the el Nino affects, while forest fires increase and desertification spreads. Pollution is growing fastest in the developing world but remains high in the North American region. Food balance may be affected as grain and other crops are highly sensitive to average temperature rises and will drive trade in foodstuffs. Telecommunications infrastructure will be aimed at resisting the extreme effects of weather and also at alleviating the disasters as much as possible, and new types of infrastructure could offer much in operating during and after cataclysmic events. A need for a citizen's alert network as part of new infrastructure is likely to appear. Telecommuting could be increasingly important in OECD countries in terms of combating pollution through reductions in fuel consumption.

Technology including telecommunications technology advances

Conventional thinking on technology for telecommunications infrastructure is changing slowly as new generations and types of computerised technology replace the circuit switched, fixed wireline infrastructures with packet (radio-based) communications, so that complementary parallel infrastructures will come into being. The key impact of technology – in lowering cost – is being implemented in Internet models of pricing of voice, with voice over IP (VoIP). A whole new infrastructure lies in the future driven by far lower cost pricing. Such an infrastructure also requires high-speed access so the advent of updating technologies for the copper local loop (xDSL) and wireless access technologies for the local loop will be increasingly important. Fibre optics can be considered as a major technology factor and the continuing advance in propagation capacity with new variations of wave division multiplexing (WDM) will continue to reduce costs per channel by orders of magnitude. In hand with this is the enormous expansion in ICT usage with Internet access which is driving infrastructure investments and its usage, as shown in the table below, even for areas such as Africa.

Table 2.8. **World Internet usage (September 2005) and population statistics**[1]

World regions	Population (2005 est.)	Population % of world	Internet usage, latest data	Usage growth 2000-05 (%)	% population (penetration)	World users (%
Africa	896 721 874	14.00	23 867 500	428.70	2.70	2.50
Asia	3 622 994 130	56.40	327 066 713	186.10	9.00	34.20
Europe	731 018 523	11.40	273 262 955	165.10	37.40	28.50
Middle East	260 814 179	4.10	21 422 500	305.40	8.20	2.20
North America	328 387 059	5.10	223 779 183	107.00	68.10	23.40
Latin America/Caribbean	546 723 509	8.50	70 699 084	291.31	12.90	7.40
Oceania/Australia	33 443 448	0.50	17 655 737	131.70	52.80	1.80
World total	**6 420 102 722**	**100.00**	**957 753 672**	**165.30**	**14.90**	**100.00**

1. Internet usage and world population statistics updated 30 September 2005. Demographics Population numbers based on World-Gazetteer Web site. Internet usage information data from Nielsen//NetRatings, International Telecommunication Union, 2005, and Miniwatts International, LLC, *www.internetworldstats.com*.

Perhaps the key pure technology advance is in forms of radio propagation for broadband data with efficient spectrum usage using advanced digital signal processing. Greater computer power combined with signalling advances is being applied at the levels of protocols for switching (for secure packet switching). However, expansion in economic trade over these new networks with e-commerce will also open the telecommunications infrastructure to various forms of attack. Mobile will offer more than communications, with multimedia content as well as satellite positioning and cell-based location services. New directions in mobile will develop with the commercial and medical/care uses of

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RFID (radio frequency identification) technology and new infrastructures may be built to handle these, as in the Korean port of Busan. Other novel technologies, such as nanotechnology for building parts of handsets, especially motive power, may be useful. Innovative energy technologies – specifically battery technologies for mobile handsets, with polymer composites having higher power densities – will be important. Local energy technologies such as solar and wind power will be required for remote networking. Space technologies, especially for lower-cost highly reliable launches might give rise to fleets of low earth orbit (LEO) satellites – which would have to change the basics of the failed business models of the first generation of LEOs (Iridium, Teledesic, etc.). The result would be a low-cost satellite infrastructure for developing regions and dense urban areas. At the social and industry level, availability of a new generation of ubiquitous radio-packet broadband will change other infrastructure elements; through teleworking perhaps, RFID will change logistics and medical/care infrastructure services.

Public decision-making process and telecommunications regulation

What is considered in the public interest in telecommunications has changed over the past two decades. Liberalisation and democratisation has had enormous influence over the ownership, structuring and operation of telecommunications networks, to their betterment technically, in services and in accessibility. We have moved away from command and control or monopoly incumbents to many countries having competing operators, and many with competing infrastructures. In the case of the latter, we have seen the entry of key new players, the mobile operators.

Separation of services from infrastructure, opening up infrastructure competition (and overall far greater competition through deregulation) has been a long-term goal for regulators, especially with the attempted opening to competitive local exchange carriers (CLECs) in the United States. This largely failed due to the maintenance of control by the incumbents over the unbundled elements. Only in 2005 was any large OECD economy (the United Kingdom) prepared to take the step of forcing its incumbent operator into an externally monitored unbundling of the local loop. Although appearing to be just an accounting system separation, this latest step depends on separation of network management systems and business support systems from the incumbent's operational support systems. It is notable that the early break-up of AT&T has largely failed, leaving the remnants of the merged RBOCs (regional Bell Operating Companies) to dominate the US market, as they moved into long-distance and mobile services, successfully fighting off deregulation with unbundling of the local loop elements to service providers such as the CLECs. Public decision making will however reign over the future telecommunications infrastructure, to a degree still varying by region and country. Harmonisation of infrastructure standards globally is necessary if competition in services, equipment and infrastructures is to be meaningful.

Part of this harmonisation will be a global or regional opening of the radio spectrum probably towards more unlicensed bands. In general we may expect to see a weakening of the national regulator against the rise of regional regulation (Europe, Asia, North and Latin America) with a global co-ordinator becoming more important, somewhat in the way that the IETF (Internet Engineering Task Force) has grown in significance as the *de facto* setter of Internet standards and processes. Regulators, through informal networks, have been learning from each other and in particular the developing economies have rapidly picked up the main regulatory frameworks from OECD countries. Whether there will be global governance in any areas with a global regulator by 2030 is open to question. Whether it will treat convergence of communications and media content as one subject is also open to surmise. Certainly there will be a long-term global discussion over Internet regulation and engineering, for its new infrastructure form as the mobile Internet, with the role of the United States becoming less dominant. Here we should note that with the growth of packet voice up to 2030, the Internet and its successors will be the main channel for voice traffic, both global flows and local connections.

In contrast, at a local level, we may expect that the coming generation of networks (based on AWTs) will often be owned and directed by local municipalities as alternative operators. Decision taking on regulation has passed through a sea change from protection of the incumbent national operator and its wholly owned infrastructure to consumer protection (*e.g.* from price gouging on termination rates internationally) and will move on towards enforcement of security measures. However, the incumbents can be expected to fight a rearguard action to protect their sunk costs in existing infrastructures and also to protect any new NGN infrastructure framework investments against the price onslaught of VoIP, claiming it will destroy Universal Service Obligation costs, and so should be regulated and high termination prices should be enforced. The United States and Japan have already accepted that new broadband network infrastructure be excepted from open availability at wholesale prices to competitive service providers.

Telecommunications pricing

A major factor, perhaps *the* key factor, driving future telecommunications demand and thus infrastructure investment, is price. The enormous sums recently paid for VoIP companies are a witness to the expected success of such low-price services. All of this is being driven by price and price competition resulting from opening the telecommunications market to both infrastructure and service competition. With media and communications convergence, multiple plays of voice calls, messaging and now TV media over broadband, competing multiple access infrastructures are being offered:

- Mobile broadband (3.5G and AWTs).

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- Mobile narrowband (2G, 2.5G and early 3G).
- Cable TV – interactive and other.
- Fixed Wireless broadband.
- xDSL local loop broadband.
- Digital PSTN (dial-up at up to 56 kbps).

Many of these local loop technologies lead back to common backbone fibre optic technologies for Internet access, but possibly via competing bulk traffic networks with service competition for Internet access (via broadband or dial-up). In such a situation current service prices can be challenged. Current voice pricing varies by call duration, time of day, distance, domestic or international, and package of bundled services, especially in mobile. In contrast Internet access is most usually flat monthly charges for all that can be consumed. For VoIP charging – for instance, the service provider Skype's tariffs for Internet telephony – they are structured around the destination of the call only and the associated termination charges, rather than, as with PSTN and cellular mobile telephony, a combination of the destination and the origin. It thus costs the same to call Japan using Skype, irrespective of whether the calling party is in Australia, France or Japan:

Table 2.9. **SKYPE international charges, 2004**

Destination	1 minute USD + tax	Destination	1 minute USD + tax
Australia	0.019	Canada (Mobile)	0.019
France	0.019	Korea (Mobile)	0.066
Italy	0.019	Japan (Mobile)	0.14
Japan	0.022	France (Mobile)	0.184
Korea	0.027	Spain (Mobile)	0.263
Finland	0.033	Italy (Mobile)	0.281
Turkey	0.125	OECD (average for countries with receiving party pays)	0.037
OECD average	0.031	OECD (average for countries with calling party pays)	0.23

Sources: SKYPE/OECD, Communications Outlook 2005.

What we see is an enormous cut in operator margins, with Skype prices across the OECD being on average 20% of international call PSTN operator prices.[27]

Microeconomic effects of inflation

Economic factors in affecting both OECD and developing nations are taking a larger dimension as oil prices rise under the influence of global conflict and natural disasters, against a background of generally rapid housing price inflation globally. Inflation in housing in the OECD group of countries and in certain parts of the developing world will influence both spending patterns and the likelihood of a recession if the housing bubble bursts. Economies are increasingly consumerist and as such are increasingly vulnerable to swings in the housing market as it is used as a mechanism for consumer-stored wealth and as collateral for consumer loans. The use of MBOs (mortgage backed obligations) has turned the housing loan market in some countries into a securitised market. Where those instruments are traded as CDOs (collateralised debt obligations) they may enter the derivatives market used by hedge funds, so that microeconomic issues may become macroeconomic problems in the event of a downturn, as Japan's continuing recession has shown. Housing prices thus limit consumer spending on other items, such as telecommunications services, despite the fact that household expenditure on communication services has been the fastest growing item of consumer expenditure.

Furthermore, housing prices are related to proximity to work, and so commuting distances are inversely proportional to housing prices, introducing scarcity rents, which may in the future drive telecommunications demand if telecommuting is possible for some days of the week. Coupled with this in commuting economies is the price of oil.[28] Acceptance by consumers of residence further from centres of work has been driven by lower house prices as long as workers could afford the commute cost. For instance, in the United States, for the extensions of suburbs ("exurbs") commutes of 100 miles per day and more are common. In October 2005 in the United States, as fuel prices reached USD 3 a gallon, the price of a 100 mile commute in a typical American vehicle with combined cycle of 16 mpg rose from USD 231/month in October 2003 to USD 407/month.[29] However this fuel price is approximately only 38% of the price in a European OECD member state such as the United Kingdom. Any solution in teleworking of some form would offer relief – the combination of housing and fuel prices will tend to drive telecommunications. Alternative public transport solutions are not a choice, as they do not exist for many countries.

3. Projected trends in demand for telecoms and investment to 2030

This section examines projected trends in demand that will change infrastructure investment. It draws on results and projections of various studies from a wide range of sources, including the World Bank, the European Commission, the OECD and the International Telecommunication Union.[30]

Accessibility, fixed to mobile convergence and mobile dominance

Throughout the development of mass technologies, less accessible services have been replaced by more accessible ones.[31] In the transport world, canals in the 18th and 19th centuries were seen as the main transport mode

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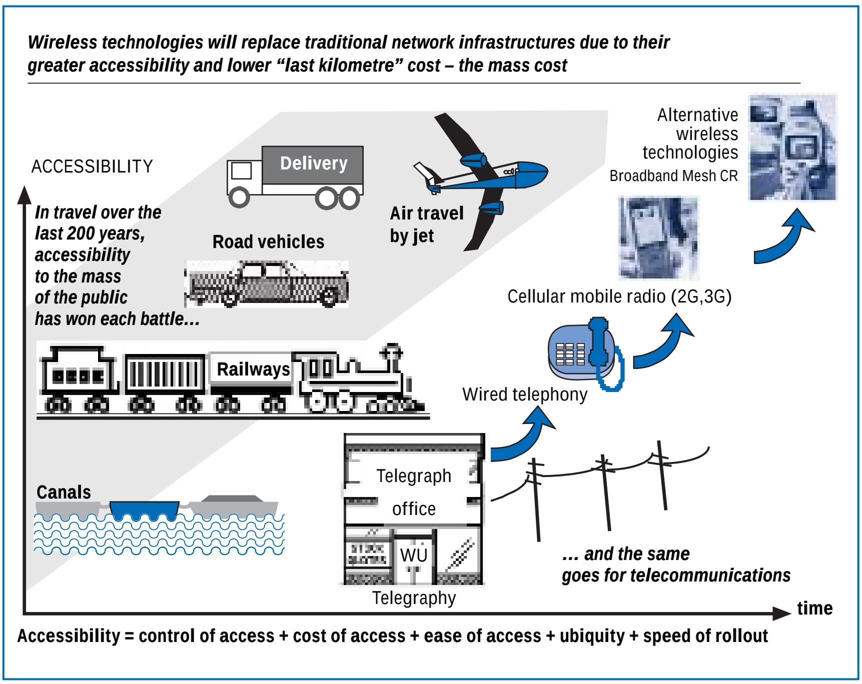
in a time when roads were often impassable for parts of the year. The canals paid for the first railway lines in the late 1820s as feeder networks, which by 1840 were the dominant transport mode globally. By the 1920s the US railroads had started to finance local feeder systems of roads, and this network by 1940 had challenged them; by 1950 roads were the dominant transport network in the United States. In telecommunications, the main American telegraph operator Western Union was offered the Bell voice telephony patents for USD 100 000 in 1875 and turned them down. Voice telephony was seen only as a technology useful to relay a local message to the Western Union telegraph office, for then sending long distance by Morse as a telegram message, as represented below.

Figure 2.5. **Accessibility and telecoms development**



Similarly, a second and more important transition is under way, from fixed voice telecommunications to mobile voice and text messaging (with SMS) due to ease of access. Mobile is far more accessible in that the mobile handset is the telecommunications equivalent of the car, which can join the telecommunications "highway" from anywhere there is coverage. And the service accessing mechanism, the handset, is in private ownership, a possession. Moreover, access is higher because rollout is far faster than fixed, due to the lighter physical support infrastructure. The local loop is instantaneous with base-station commissioning, and only demands construction of a fixed "core" (or trunk backhaul) network, which can be quite rapid especially if an existing trunk infrastructure can be used to some extent. Thus, the trend in consumption of telecommunications and its supporting infrastructure is to ever more mobile communications. So far that has been in cellular mobile. But by 2030 new mobile technologies currently grouped under the heading of Alternative Wireless Technologies (AWTs), such as WiMax with lighter infrastructures, will have an increasingly important part to play for both economic and technical reasons.

The power of a consumer economy – the rise in income and the fall in tariffs to near-zero levels – to produce a global infrastructure for all

Today's economies have moved from being agricultural, to heavy and light industrial, to consumerist. Falls in consumer spending no longer reflect recession – they precipitate them. The rise in telecommunication usage is a consumer movement, driven by mobile take-up by a global user population. As incomes rise and the cost of telecommunications falls, the number of users and their usage is increasing. For the world's poorest, mobile offers many the first and only chance to telecommunicate. The main driver therefore of this global expansion in the user population is disposable income. GDP per head is not accurate as an indicator of personal gross (or disposable) income, but it is a useful trend indicator. Current disposable income according to the World Bank is examined in the Table 2.10.

The table shows that some 2.4 billion people are in the annual income bracket of USD 765-3 035. At this level they are on the point of being able to afford mobile telecommunications, or already have it, for a phone costing under USD 40, lasting 1-2 years, and with call cost expenditures of USD 5-10 per month and under. Of course, the potential is far larger, with 4.8 billion people having under USD 3 035 per annum, an enormous market. It is *the* future market for the global mobile operators, who are all studying it carefully due the surprising rise of mobile in poor African and Asian states. In Africa for instance, from a very low base, subscribers have expanded 1 000% between 1998 and 2003, entirely through private investments, and mobile plays an increasingly crucial part in economic development.[32] Mobile penetration in some poor developing countries has even reached over 30% of the population, such as South Africa with 36% in December 2004.

Most importantly, rising disposable income in the NICs up to 2030 is estimated to increase, changing the above table. In China for example, household incomes of near USD 5 000 at today's prices (€ 4 160, Oct 2005) are expected to be attained by some 90% of households by 2014, up from 17% now according to Credit Suisse First Boston research[33] because the numbers of households having this income are estimated to be increasing at 24% per year. Even if these figures

Table 2.10. **Disposable income by region, 2004**

			Per cent			Annual GNI/head
World population	**6 345 127**					
Low income	2 338 083		37			< USD 765
Middle income	3 006 230		47			USD 765-9 386
Lower middle income	2 430 310		38			USD 765 to 3 035
Upper middle income	575 920		9			USD 3 035 to 9 386
Low income and middle income	5 344 313		84			
East Asia and Pacific	1 870 228		29			
Europe and Central Asia	472 073		7			
Latin America and Caribbean	541 322		9			
Middle East and North Africa	293 994		5			
South Asia	1 447 673		23			
Sub-Saharan Africa	719 022		11			
High income	1 000 814		16			> USD 9 386
European Monetary Union	307 446		5			> USD 9 386
	Low income		Lower middle income			
Under USD 3 035	2 338 083	+	2 430 310	=	4 768 393	
% age world population						75.15

1. World Bank Indicators database, 2004, produced 15 July 2005.

are too optimistic, nevertheless, the direction is clear – the numbers of Chinese able to participate is certain to grow. The consumer milestone of USD 5 000 as the threshold of disposable income is related in telecommunications cost in terms of current tariffs. Ultimately tariffs will be set in a competitive market and this means that prices will fall.

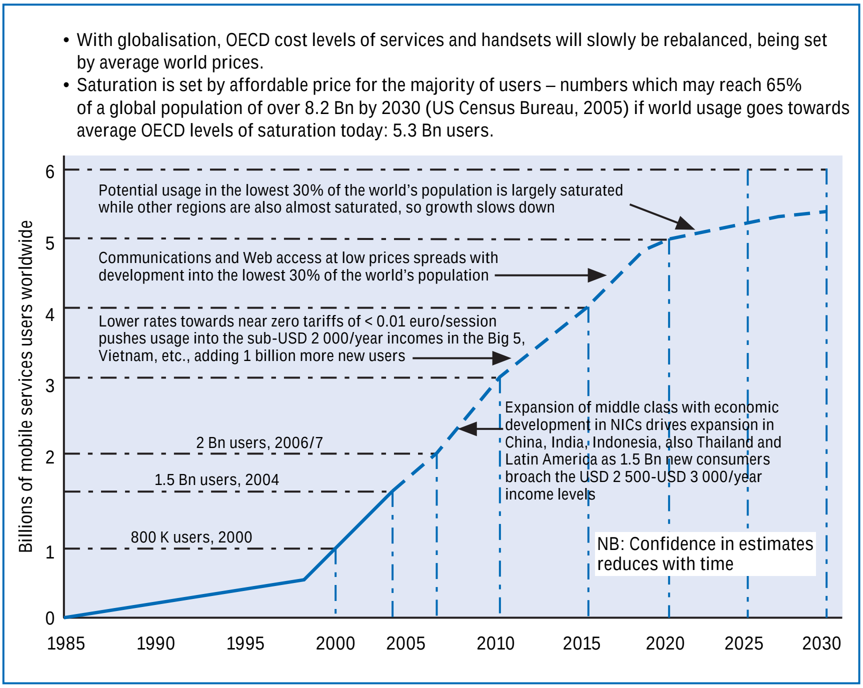
Impacts on global demand of rising incomes in the developing world

What we can expect is a major expansion in the numbers of mobile users, firstly up to 2010 as the disposable income rises for around 1.5 billion people around the world, especially in China and India. However in the next phase, the power of the new consumer economy in the developing world will destroy the margins of the incumbent operators built up over the past 100 years through competition, as depicted in the Figure 2.6.[34]

Beyond 2010, some one billion new subscribers, as described above, may be expected to enter the market as tariffs reduce, with new networking technology which has lower costs and faster rollout. Handset prices in mass production can also be expected to sink. Nokia is already selling simpler handsets that cost under USD 30 to produce and by 2010 global low-end handset prices of USD 10-20 can be expected from Asia.

However when tariffs are genuinely cost-based due to competition, the price of a call can be expected to fall to fractions of a US cent. This gives impetus to a

Figure 2.6. **Global user population growth**



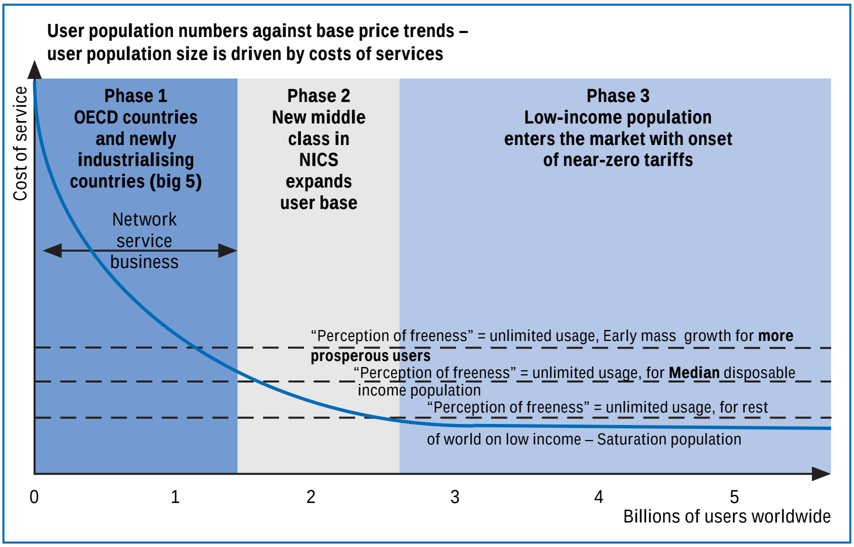
massive new consumer market in the years up to 2015 created by the expansion of disposable incomes principally in China and India, but also in Brazil and other Latin American economies, and possibly also in Russia and Indonesia.

The main trend – expansion in demand with rising income and price falls

In general we can say that the main trend in demand for telecommunications that will drive infrastructure is a massive expansion of demand globally from developing countries, firstly as incomes increase to around the USD 3 000 level. Secondly we can expect take-up for those below this income level, as prices fall.

This is summarised in the following figure in terms of Dupuit curves for the take-up of public services. We can expect three phases – early takeoff in the OECD community followed by the growth of the middle class in the developing world. Falling prices drive entry to a further phase of expansion – those with incomes below USD 2 000. However demand has been found to be non-linear and to expand suddenly at a certain price point[35] – *the perception of freeness* – whereby the consumer perceives that calls are effectively free and will be used without constraints due to cost.

Figure 2.7. **Demand takes off at a certain price point – the perception of freeness**



Trends in traffic and their infrastructure impacts

With their ability to reduce costs, there will be a move towards higher bandwidth infrastructures, initially driven by the need for Internet access. Multimedia will tend to replace plain vanilla voice to some extent, although this will be a slow transition. Voice and SMS will always dominate, especially in the developing world, as they are the enduring basic services with key needs in the low-end market. Only a slow transition from these two basic services can be expected, into downloaded music, video games both networked and downloaded, possibly limited usage of DVB-H TV video programmes, etc., over mobile broadband links as consumer disposable income rises in the most affluent customer segments globally. In summary we see a move to broadband content which requires support for isochronous media (audio, video and data where packet order and delays are important) requiring careful packet management in assembly and disassembly.

Individual consumers will also generate their own content themselves, and exchange it. The rise of peer-to-peer content in all forms of media (video, audio, text) is expected to grow in importance, as much as commercial sale of content (TV, music, etc.) from the industry players – the content providers and aggregators. This will tend to increase the bandwidth required, and make the use of asymmetric networks (where only download speeds are high) far less viable as many customers will want to upload content as well.

In later years, beyond 2015, an increasing component of traffic is expected to be machine-to-machine communications and transactions over the Internet, especially in industrial applications such as supply chain, process control and also in financial transactions for person to machine. An "Internet of things" will grow up. Machine-to-machine communications for industrial and consumer functions and person-to-machine, for instance to make purchases, will be increasingly an everyday event. The impact on infrastructure will be to increase not only the traffic, but the address space required for all the new respondents.

Demographic trends with infrastructure impacts

The ageing demography will tend to push telecommunications into new uses requiring augmented infrastructures. Trends in demand for support services for the elderly and in health care could seed completely new extensions of current infrastructures, especially in wireless – for the areas of individual lifestyles and business that cellular mobile services cannot support. Some of the key applications will rely on various forms of sensor networks. Two major applications can be envisaged here – wireless local networks for health care and elderly care including linkages for the use of near field communications (NFC) technologies in body area networks.

Trends in response to global warming and natural and manmade disasters

Trends towards increasing numbers of natural disasters such as global warming (inducing hurricanes, ocean current perturbations, sea level rises, flooding and seasonal change, etc.) as well as tidal waves, earthquakes, etc. will require new and better security emergency systems and emergency services for physical security. These events will make new infrastructure demands, which must also cope with response to terrorist threats. Such events require physically separate multiple infrastructures which are highly robust and autonomous with the power to be rolled out instantly, to be set up in *ad hoc* deployments as required. New types of networks based on mesh technology and cognitive radio front-ends can be expected, which can be instantly rolled out.

Insecurity and ICT

A further trend that will influence infrastructure is the build-up of insecurity by users at several levels – for personal safety as well as for protection against identity theft, fraud through a widening variety of mobile and Internet scams as well as transaction security for shopping and banking. Here we have to ask – what is infrastructure? For a secure Internet access it is no longer just outside plant. It is layer of addressing, session control, authentication of identification of senders and receivers. Thus infrastructure in a world of "man in the middle" attacks and other more sophisticated fraud mechanism needs a layer of in-built security for authentication and authorisation with audit for access control.

Conclusion

The telecommunications industry has been notoriously poor at forecasting the take-up of new technologies and services, largely because market forecasts have often been supply driven and technocentric and do not focus on understanding consumers' behaviour and their needs – and what they will pay for. In the recent past this led to misplaced optimism for technologies such as ISDN and WAP. Even now, the industry is repeating the same mistakes. Its forecasts for 3G mobile, based on a combination of extrapolation of past trends and wishful thinking, has led to overoptimistic forecasts for the takeup of multimedia services.

A better approach to forecasting is to identify and understand the underlying trends and their drivers, and to take a demand-driven approach. Firstly a more global view of the market is now essential. This perspective provides an understanding that the overall telecommunications market has the potential to grow to three or four times its current size in terms of the number of consumers, by expansion outside the OECD group. Thus pricing is important and this will be the key stimulant for consumer take-up.

A second key finding is that "content is not king"; instead it is connectivity that consumers will pay for as their primary motivation as this new market opens. However, later on, content could become far more important as attractive multimedia services appear.

Third, wireless technologies are developing rapidly and allowing infrastructure to be rolled out more cost effectively than ever before, offering the promise of connectivity anytime, anywhere, and at ever lower prices – a key attraction for consumers. As new wireless technologies become integrated into a network of networks, and costs fall, these services will become accessible to the world's growing middle (and eventually lower) classes in the developing countries.

4. Impacts of key drivers on future investment in infrastructure

This section explores the possible impacts of the selected drivers on future demand for infrastructure and infrastructure investment.

The historical significance of telecommunications in total infrastructure spend

We can see that the drivers towards an information society have modified infrastructure spend so that the proportion that is telecommunications has increased over the last forty years as a percentage of total infrastructure spend. Table 2.11 shows an estimate from the World Bank, for the short term, of increase to be 10% in 2010, up from 2% in 1960 (when rail accounted for almost a third of the value of infrastructure). In contrast, electricity's proportion has doubled from about 22% to 44%. Telecommunications more than tripled up to 2000, albeit from a very low 2%, with its increasingly central role in today's society.

Table 2.11. **How the composition of infrastructure stocks has changed over time, all countries**

In per cent

	1960	1970	1980	1990	2000	2010
Electricity	22	32	40	43	44	42
Roads	47	46	45	44	44	43
Rail	29	19	13	9	6	5
Telecom	2	3	3	4	6	10
Total	**100**	**100**	**100**	**100**	**100**	**100**

Note: Water and sanitation excluded as lack of historical data.
Source: Marianne Fay, Tito Yepes, *Investing in Infrastructure, What is Needed from 2000 to 2010?,* Policy Research Working Paper 3 102, The World Bank, Infrastructure Vice Presidency, July 2003.

How will telecommunications infrastructure growth proceed in terms of level and qualities? A discussion follows of the impact of the various drivers explored previously, especially that of disposable wealth.

Cost pressures reshape infrastructure

For many people, use of the Internet is now perceived as being free. But how did this happen? In the five years up to 2000/01 certain singular events, never seen before in the industry, specifically the temporary imbalance between bandwidth supply and demand and the financial markets' over-exuberance in financing expansion, created a public Internet at low cost to the consumer. To some extent, this was precipitated by the one-off events in the US telecommunications markets which, due to its very nature, spread globally. In consequence, downward pressures of VoIP on revenues of the OECD's carriers of domestic and international traffic may be expected in the long term, and will be an irreversible trend. What is significant for the incumbent telephone operators, and their infrastructures, is that VoIP technology will require severe cost containment action as margins fall. It will drive adoption of a business model based on the Web service operators as VoIP technology expands its hold, driven by suppliers such as Cisco and Intel as much as the new competing service provider entrants.

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Such revenue declines will be offset by continued strong demand for mobile radio services of all kinds worldwide, especially expansion in the less developed countries. But revenue gains in these segments cannot restore declining operating margins, as revenues from voice service decline. That can only be achieved through base-cost reductions, principally in two areas – operating business model and infrastructure capital spending, cost of capital and operating costs. Early research is not yet clear but some sources suggest that, worldwide, revenue losses due to international VoIP amounted to USD 74 billion in 2002, about 7% of service revenues, which stood at some USD 1.04 trillion.[36] As we go forward, there are conflicting views.

One US view is that by 2011 revenue losses due to international VoIP bypass will have risen to USD 96 billion – a loss which would represent only 5% of total telecom service revenues of USD 1.8 trillion at that time.[37] This is quite an optimistic view for the incumbents. In opposition are views that the loss could be far higher as major operators (BT, France Telecom/Orange) install new all-IP infrastructure, while the new competitors expand through major capital injections and buyouts by large groups with investment resources (such as the eBay purchase of Skype) for new ISP type business models, where voice is an adjunct service, not the principal offering.

In this scenario, the percentage decline in international service revenues due to VoIP bypass could be far larger. Voice tariffs could on average reduce by up to 90% towards "near-zero" tariffs by 2015. This effect would be most marked outside the OECD group due to stronger competition, as migration of voice traffic from circuit-switched to packet-switched networks for all traffic is approached. Although international voice traffic volume would continue to rapidly expand, it could not offset the declining rates in terms of total revenues, even with the growth of the mobile subscriber base in developing nations – due to the tariffs their disposable income affords. In Asia, 2004 VoIP bypass calling revenue amounted to more than 33% of the USD 98 billion spent in China, India, Japan and other Asian countries on international calling.[38] In the US view, by 2011 VoIP bypass revenue is expected to remain essentially flat at USD 30 billion while total international call revenue jumps to about USD 160 billion.[39] In this view, of the 96 billion Asian international calling minutes of use forecast in 2011, only around 25%, some 22.8 billion minutes, would be attributable to VoIP. However looking at recent growth (33% of all minutes effectively since around 2001), expected regional economic development (around 6-8% per annum) and the rollout of better quality technology for VoIP in Asia, projections of both overall call volume and proportion of VoIP seem low, when taking account the low cost of calling and the expansion of trade, offshoring and migration of workforces. Lowering costs could accelerate international telephone traffic (as VoIP) by a minimum of 10-20% per annum as new consumers enter the disposable income bracket (suggested as 24% per annum in China) for international low cost calls. In compensation for the loss in voice revenues it might possibly be expected that prices for fixed lines would increase and that operators would introduce flat rate unlimited voice packages. However, raising prices for fixed lines would tend to accelerate the migration towards mobile for the ordinary consumer.

Government and private sector roles in the markets-led model

Private sector-led growth in infrastructure investment has revolutionised access to telecommunications services around the world over the past ten years. For the OECD community we see that deregulation has allowed new pricing regimes, not controlled by the incumbents, and specifically the VoIP market to take off, despite attempts to ban or restrict it in some countries. However in developing countries, two competing assumptions regarding the build of telecommunications infrastructure are that "the private sector alone is enough" and "the government must take the lead role." Obviously, the private sector and governments both have crucial roles to play in ensuring that a growing percentage of the population of the developing world can access modern communications. Using the private sector, every region of the developing world will benefit in terms of investment and rollout.[40] In consequence we can expect this balance to continue in the financing of the new infrastructure using private capital under public guidance through flexible guidelines.

The key growth regions for telecommunications infrastructure, as outlined above, are in developing countries. While progress has been made in closing telecommunications supply gaps here, there is still a very long way to go, both to fill existing domestic supply gaps and also to meet growing demand for global telecommunications services. To continue recent rates of progress and reach a fixed and mobile teledensity of 11.4% in low income countries, and 91.2% in middle income countries by 2010, the developing world will still need to invest about 1.2% of its GDP per year, or over USD 100 billion, in new capacity.[41] Sub-Saharan Africa alone will have to invest USD 3.8 billion each year in new capacity. And these figures do not account for growing requirements to fund broadband, for example.

Table 2.12. **Short-term annual requirements for developing world telecommunications investment, 2005-10**

	New capacity	Maintenance USD m
Developing World USD m	104 986	82 040
Developing World % GDP	1.24	0.96
Sub-Saharan Africa, USD m	3 814	2 834
Sub-Saharan Africa, % GDP	0.82	0.61

Source: Fay and Yepes, 2003.

Suitability of current technologies for future infrastructure

Fibre in the local loop

In the 1970s, telecommunications operators began to deliver a higher quality of voice service to subscribers in remote, rural areas by a new infrastructure topology which placed the electronics in the outside plant network, rather than inside the traditional central switch exchange office protected environment. Following this, in the 1980s, industry commentators predicted that in many countries infrastructure investment in the local loop would bring broadband services over fibre into the home (FTTH) or office (FTTO) in an all fibre network (AFN), which was expected to be complete in OECD countries by 2005.

In the mid-1980s, the cable TV operators with switched star fibre optics networks for full interactivity then took the lead.[42] However, the AFN has not developed in the way that many expected. While FTTH or fibre close to the customer is envisioned by some as the preferred access technology of the future, it is certainly not assured. Hybrid fibre/copper-coax (HFC) networks in the local loop have taken off in the OECD area, especially as broadband demand soars with signaling via DSL. At the current rate it would be decades before FTTH was widely available across the OECD countries. This slow take-off is for reasons of cost, outlined in Table 2.13 for remote equipment (hardened) and protected environments (non-hardened).

Note that these costs of FTTP, or even HFC DSL are well beyond the infrastructure costs of developing countries, which also may not have a favourable topology for passing homes and offices. Capital cost per home or office is sensitive to loop lengths (and hence to housing/building densities) and thus it is necessary to consider three deployment scenarios: urban, suburban and rural. Using the table above, the costs of a local loop infrastructure as an average for the United States, for approximately 200 million homes and offices, for FTTP would hence be of the order of USD 3.4 trillion. For HFC using a shared cabinet (for 300 connections) it might come down to about USD 200 billion, at today's prices, not an inordinate sum for infrastructure for the United States. But could this be done more cheaply with some other technology? Moreover, to minimise distances to each subscriber (a critical factor in the amount of bandwidth delivered) service providers have to place the electronics for HFC DSL in more locations throughout the network, and a higher density drives up costs.

Deployment of broadband networks capable of delivering the triple-play services (TV, Internet and voice telephony) may mean that for fibre-based local loops, fibre will be placed deeper into the access network, closer to the premises. The service providers' decision as to where to place the electronics and terminate the fibre will have a major impact on how the network is costed. Pioneering countries like South Korea are installing fibre closer to the customer – within less than a kilometre via fibre-to-the-curb/cabinet/basement – and using copper

Table 2.13. **Deployment installation costs for local loop fibre pure and hybrid schemes, USA, April 2005**[1]

Fibre deployment to premises, FTTP (FTTH, FTTO)	**Passive optical network**	**Active optical network**
Maximum copper length	0 ft	0 ft
Minimum estimated bandwidth	62.5 Mbps	62.5 Mbps
Assumed take-up rate	50%	50%
Cost per Subscriber	USD 7 104	USD 3 970
Cost per Subscriber, home passed	USD 2 802	USD 1 782
Hybrid Fibre and Coax from remote cabinet Serving area interface, SAI deployment or fibre to the node, FTTN 5 000 feet from remote cabinet via 20-Mbps ADSL2+	**Non-hardened remote DSLAM (digital subscriber line access module)**	**Hardened remote DSLAM**
Maximum copper length	5 400 ft	5 400 ft
Minimum estimated bandwidth	16 Mbps	16 Mbps
Assumed take-up rate	30%	30%
Cost per Subscriber	USD 668	USD 496
Cost per Subscriber, home passed	USD 169	USD 114
Hybrid Fibre and Coax – fibre to the curb (FTTC) then coax to premises, home or office	**Non-hardened remote DSLAM**	**Hardened remote DSLAM**
Maximum copper length	900 ft	900 ft
Minimum estimated bandwidth	35 Mbps	35 Mbps
Assumed take-up rate	50%	50%
Cost per Subscriber	USD 2 382	USD 1 778
Cost per Subscriber, home passed	USD 953	USD 758

1. Mark Labbé, "Laying the Fiber: A Detailed Cost Analysis – Plan to reuse and adapt infrastructure as fiber evolves to the home", *Broadband Properties*, April 2005, available at *www.broadbandproperties.com*, with a model that uses an average North American topology.

(usually coax) for some form of DSL for the last several hundred metres. VDSL technology on this short copper loop can provide downstream service rates of up to approximately 30 Mbps, matching bandwidth capabilities of FTTH.[43] Thus copper DSL will be one method of delivering broadband services for many in the OECD community for decades to come. Currently DSL is growing strongly in the OECD area (Figure 2.8) as a new infrastructure component with expanding availability but still has a long way to go, as shown by its growth in 2005 reaching the first 100 million subscriber connections:

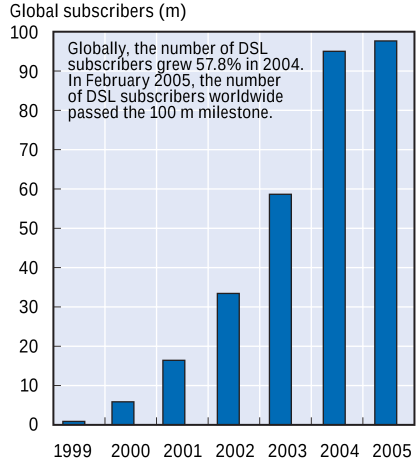
For cellular mobile Internet access, Japan has led the way with 70 million subscribers by mid-2004 for all mobile Internet services, with over 40 million of them using DoCoMo's i-mode.[44] Korea is following with other wireless broadband systems based on IEEE 802.16 (WiBro); the United States and European countries are considering this and also installing the i-mode 2.5G cellular technology (France, Belgium, Netherlands, Spain, Greece, etc.). There are also suggestions that the latest in cellular mobile can be used as a broadband local loop technology, that is UMTS 3G mobile offering 2 Mbps, which may also have data

Figure 2.8. **DSL % availability in GSM**

DSL % availability in G7	2001	2002	2003	2004	2005 Projected
UK	60	64	85	95	99
Canada	69	70	75.4	75.4	75.4
France	66	71	79	90	95
Germany	70	80	85	90	n/av
Italy	67.5	70	80	n/av	n/av
Japan	73.5	80	90	90	n/av
USA	50	68	75	84	n/av

n/av = not available.

Source: OECD Communications Outlook 2005, Table 4.12.



Source: DSL Forum/Point Topic fibers.org *http://fibers.org/articles/fs/9/4/2/1/FSEdsl1%5F04%2D05.*

rate enhancements for uplinks and downlinks (HSPUS and HSPDS). However, when examined closely, 3G mobile seems to be an expensive technology, although capital costs are now falling for outside plant networks. But the costs of the multimedia systems, specifically the IP Multimedia Subsystem (IMS), could add additional billions of dollars per network.

Start-up costs are high for such a system to give 95% coverage in a fairly densely populated OECD-type economy. Initial capital and capitalised operating expenses pre-launch can approach USD 10 billion, as estimated in Table 2.14. After 10 years of capital write-offs of the original investment, the cost per subscriber with Opex is still USD 545 without the licence costs, while the (operator-subsidised) cost per call at launch can be as high USD 18, as shown for one example of a UMTS network for an OECD country in the table. Opex costs may be higher if more is spent on customer acquisition, especially handset subsidy.

The emerging technology mix in infrastructure in the short/medium term

In consequence, in the OECD community we can expect a mix of competing infrastructures, technologies and operators to continue over the coming decade at least. The expected mix is shown in Figure 2.9.

However there may be other technologies that could deliver both local loop and long distance at even lower cost. The cost base is such that the situation depicted in the figure above will not last forever, especially with new technologies developed in the NICs and feeding back into the OECD community. Already China is launching its own form of 3G mobile, TD-SCDMA, and we can expect new

Table 2.14. **Infrastructure costs for UMTS 3G mobile cellular**

Cost budgets of a 3G mobile network covering 95% of an OECD economy's population, excluding licence costs

Year	Pre launch	1	2	3	4	5	6	7	8	9	10
Customers 000s		1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	10 000
Calls per subscr per month		100	100	100	100	100	100	100	100	100	100
Calls per year millions		600	1 800	3 000	4 200	5 400	6 600	7 800	9 000	10 200	11 400
Infrastructure USD m	6 000	100	100	100	100	100	100	100	100	100	100
Capitalised Opex USD m	3 000										
Opex USD m		2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Cumulative calls Millions	0	600	2 400	5 400	9 600	15 000	21 600	29 400	38 400	48 600	60 000
Cumulative Capex USD m	9 000	9 100	9 200	9 300	9 400	9 500	9 600	9 700	9 800	9 900	10 000
Cumulative Opex USD m	0	2 000	4 000	6 000	8 000	10 000	12 000	14 000	16 000	18 000	20 000
Cumulative cost USD m	9 000	11 100	13 200	15 300	17 400	19 500	21 600	23 700	25 800	27 900	30 000
Capex per call USD		15.17	3.83	1.72	0.98	0.63	0.44	0.33	0.26	0.20	0.17
Opex per call USD		3.33	1.67	1.11	0.83	0.67	0.56	0.48	0.42	0.37	0.33
Total cost per call USD		18.50	5.50	2.83	1.81	1.30	1.00	0.81	0.67	0.57	0.50
Total cost USD per subscr/year		11 100	4 400	2 550	1 740	1 300	1 029	846	717	620	545

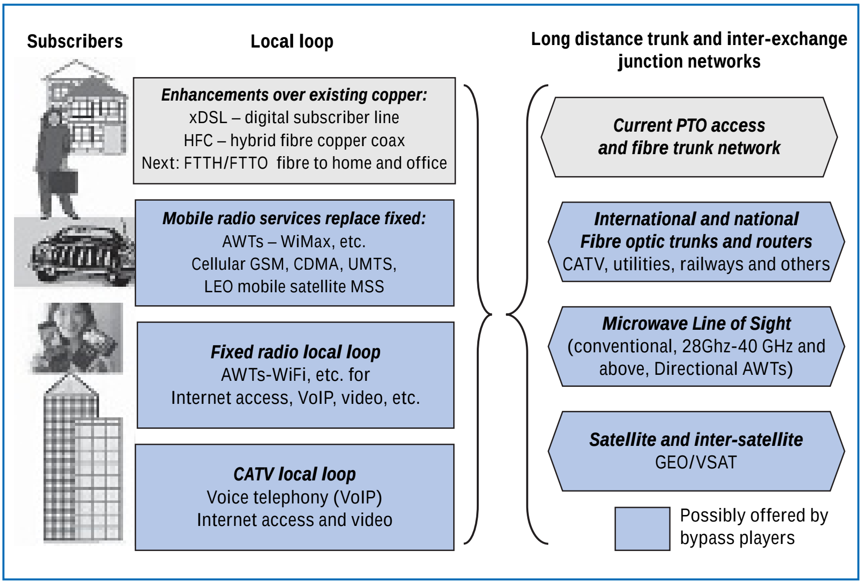
Source: SCF Associates Ltd, estimates from industry sources.

technologies for radio-based services to arrive from Korea and Japan as well as China. For instance Korea has formulated and is installing a low-speed version of its wireless broadband, WiBro for 1 Mbps broadband.

New infrastructure models for new investment returns

The nature of infrastructure investment is changing to a new infrastructure model for the long term, using lower cost technologies for broadband access and offering far more than narrowband voice (and SMS) services. Perhaps surprisingly, the way forward is being adopted equally by the incumbent traditional telco operators as much as by their rivals from the Internet world who grew up with IP packet routing. The common direction is a data communications model – even though VoIP breaks incumbents' hold over the local loop. In the OECD countries, VoIP may reduce market power progressively. There are more advanced exceptions such as France where already IP voice operators such as Free, part of the Iliad Group, have 8% of subscribers connected, via DSL, and VoIP penetration is expected to increase to 40% in 2007, with France Telecom forced to offer competing residential services since June 2004.[45] The local loop will still remain important for access and therefore will still be a bottleneck, that can only

Figure 2.9. **The low cost infrastructure to 2015 – a mix of competing infrastructures, technologies and operators**



be challenged by bypass technologies such as mobile to the home or competing fixed infrastructure (Iliad in France has 70% of its customers on its own network fibre and DSL lines). Incumbent operators are prepared to go down this route because the market for high tariff voice is diminishing but the market in Internet connectivity is taking off. BT has even been forced into challenging Skype on pricing, is using it to sell broadband local loop connections.[46] And as emphasised above, the largest unfulfilled market is in the developing countries whose disposable income is rising but at a level that demands far lower costs. So investment levels are being driven lower, not higher, as cheaper infrastructure models must appear to satisfy moves towards near-zero transport tariffs. Evidently a new model is needed, but what will this be?

Although it is unlikely that local loop mobile access will provide the same broadband speeds as the fixed local loop (France's Iliad offers up to 24 Mbps) we can already see that the TV and entertainment conglomerates without a wired access are trying to get to the customer through broadband wireless. Future digital signal processing technology for compression will be key here. For example, DirecTV, part of News Corp, has been investigating WiMax for a 2-way service[47] with the aim of providing interactive Internet access as well as entertainment video. Incumbent fixed operators also see wireless broadband as an adjunct technology for Internet access with fast rollout. Bell Canada and Rogers Communications (CATV) have a joint venture to use ClearWire technology for wireless Internet access for 40 Canadian Cities and 50 rural communities, mostly to compete on infrastructure in Western Canada against local incumbent Telus.[48]

All IP networks

It is clear that many, if not yet all, large incumbent fixed line network operators are moving to this new form of infrastructure. Interestingly such infrastructures make a future consolidation into larger global carriers far easier. Most incumbent operators of fixed line networks are now or have been examining the possibilities for "the public switched network of the future". Underlying this task is the need to look closely at the investment cost of a complete overhaul of the network, into a full IP-based network.

There are several examples of the new types of network intended to provide multiple access to many different types of network. The objective is to move the PSTN from a circuit switched voice-centric model to a data communications model which is agnostic as to the media carried. In consequence, it must be capable of isochronous packet re-assembly. It must have security built in, far more than the current Internet technology, especially for protection of VoIP. The foundation is IPv6. Such networks are often being constructed as a federator for other networks. One major application here is the transport of backhaul mobile traffic, from other operators but also for expansion of the broadband local loop, be it by forms of xDSL, or the broadband wireless access technologies being proposed in Korea and now in the United States (by Nextel) for Internet access.

One prime example for detailed examination is BT's IP network architecture with its 21st Century Network Project (21CN). 21CN is a complete IP infrastructure, being rolled out to 2008. It is based upon multi-protocol label switching (MPLS), that carries voice, data and Internet services over the one network, rather than today's multitude of networks offering specific services. BT sees that services like ATM, TDM, frame relay etc., beyond the access network layer, can be collapsed into a far simpler structure – a core – based upon existing MPLS and DWDM (dense wavelength division multiplexing) technologies. MPLS offers high-performance packet switching along predetermined paths and also uses unique route distinguishers.

A vastly simplified core reduces the number of copper pairs and fibre in the system. It means fewer network elements and simpler network management. It also reduces the number of service management organisations, equipment in outside plant and buildings. It will reduce the number of different technologies in the network, and so reduce operating costs. In the 21CN, BT has combined MPLS technology with traffic engineering techniques that differentiate between time-critical, high-priority traffic, and delay-tolerant, low-priority traffic. 21CN should reduce the complexity of BT's infrastructure with claimed elimination of 100 000 network components by establishing a single platform that is multi-service and future proof, on IPv6.

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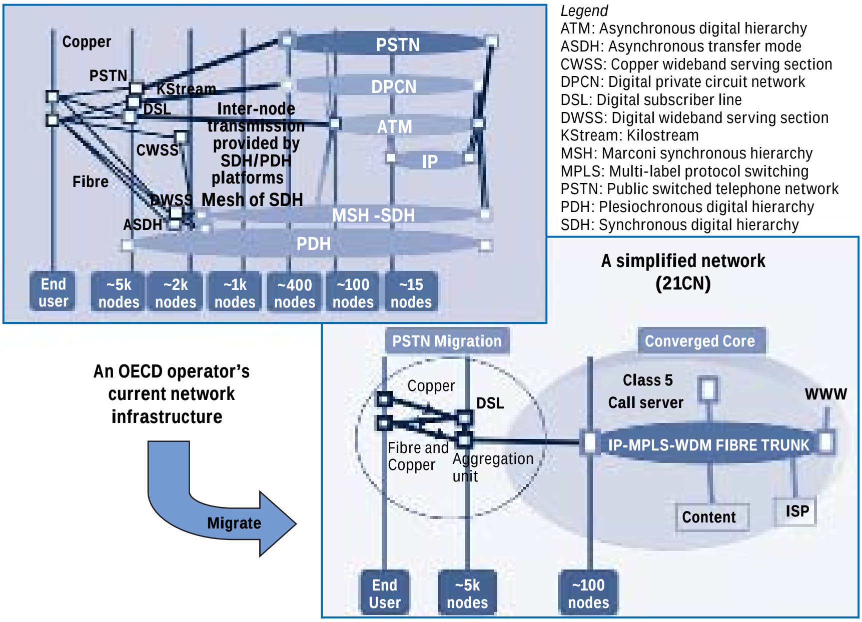
Figure 2.10. **21 CN's simplified core**



For the ordinary consumer, BT claims its 21CN will deliver more choice, control and accessibility, as well as increased flexibility, reliability and security. For private networks for large corporate customers, the "route distinguishers" using packet header information segregate the customers' Virtual Private Network (VPN) traffic. Existing VPNs become micro-versions of the whole 21CN network architecture, with any-to-any connectivity and traffic prioritisation. 21 CN also offers a simpler service management model, for greater efficiency in dealing with customers. By 2009, "broadband dialtone" will be available to most BT customers in the United Kingdom. Customers will be able to switch lines to broadband use themselves with no physical work required at the exchange.

Long distance fibre – the cost enabler

The major change in the cost of infrastructure has been in long distance transmission, be it national, international, terrestrial or sub-sea. The technology of the "global backbone" has reduced in price by several orders of magnitude over the past decade as bandwidth per link has increased at the same rate. This has enabled the growth of the Internet, one part of the global fibre network. But all growth is highly dependent on economic circumstances, and (over-) availability of capacity.

A critical element of that global backbone is the world's ever expanding network of submarine fibre optic cables. Over the past decade, the increased demand for bandwidth driven by the Internet, as well as the continuing international trend of privatisation of national telecommunications industries, has outstripped by far the resources offered by satellite transmission of voice and data.[49] Instead, the fraction of transoceanic voice and data transmitted over undersea cables has grown in the past 12 years from 2% to as high as 80% in 2000.[50] As demand has grown, so have the numbers of cables on the seabed. Geostationary satellites have progressed for long distance transmission but their cost, limitations, reliability and delay over geostationary orbits has left them as a redundancy backup for WDM fibre.

A key market for study of long distance infrastructure economics is the transatlantic traffic (TAT) market with its multiple generations of cables being the milestones of its evolution. The first optical cable was TAT-8 in 1988, with (2 + 1)*280 Mbps PDH capacity.[51] Currently TAT-12/13/14 are all in service. The typical price for a complete system (cables, repeaters, equipment at the landing points, all marine operations) has always seemed to stabilise at about USD 500-600 million, despite falls in dollar prices of equipment and increase in performance. In the initial forecasts made by the TAT-8 consortium it was expected that the cable capacity would be filled by the year 2000 – it was filled in 1990, six times faster than foreseen. TAT-14 entered service in 2001, expanding capacity more than 1 000 times that of TAT-8 in the 12 years since its launch.[52]

The international Internet is composed of private cross-border IP links deployed by over 450 ISPs worldwide. Their networks, when combined and scaled to capacity, define the global Internet capacity. Under recessionary economic influences, and the bursting of the dotcom bubble, the global Internet's expansion took a downturn in 2002. Since the introduction of the Web browser in 1994/95, international IP bandwidth deployment has more than doubled each year. But the growth rate of international Internet bandwidth slowed to less than 40% in 2002.[53] Europe, which accounts for 82% of the world's cross-border bandwidth, increased international capacity by 35%, a steep decline from 191% growth in 2001. Slowing Internet markets in Europe contributed most directly to the global deceleration of international Internet capacity growth, but developing markets also slowed. Asia's Internet bandwidth increased by 55% in 2002 compared to 122% in 2001, and Latin America's international Internet capacity slowed to 65% in 2002 after expanding from a low base by 471% in 2001.

Advances recently in fibre optic transmission are due to reductions in cost per channel using multiplexing techniques in which light beams of different wavelengths are propagated over a single fibre, and termed wave division multiplexing (WDM). Using WDM, a transmission of 10 Tbps over one fibre was first demonstrated in 2001. 273 channels of 40 Gbps each using a 50 GHz channel spacing were transmitted over 117 km.[54] This is equivalent to

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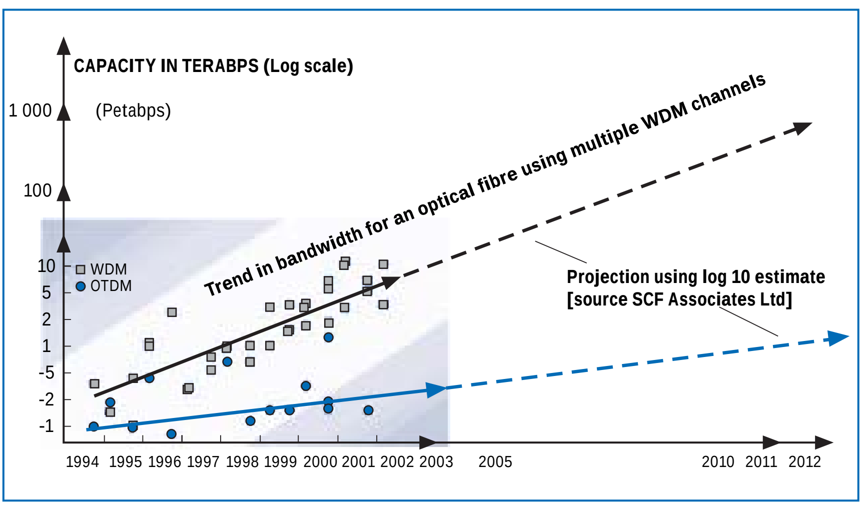
625 million voice channels at 16 kbps/channel. 10 such fibres could carry the traffic of everyone in the world speaking at once. Figure 2.11 shows development in WDM, and competing OTDM (optical time division multiplexing) up to 2003 with projected estimates of continued research following past performance, and assuming no major barriers and no sudden step change up by novel techniques. Two of the results of the WDM points in the figure below represent the first time more than one Tbps was transmitted over transoceanic distances with single channel bit rates of 40 Gbps. The results demonstrated that it is possible (but a challenge) to use 40 Gbps per channel for transoceanic systems with capacities above 1 Tbps.

The long distance fibre network can be expected to grow in both bandwidth per channel (wavelength) and number of wavelengths per fibre but projections are few due to the current bandwidth glut. In one hypothetical scenario created in 2000, it was predicted that by 2010, the bandwidth per wavelength would be 160 Gbps, for 1 000 wavelengths per fibre – that is 160 Tbps per fibre.[55] The projections above would indicate that this may be an underestimate. We thus have the capacity for massive bandwidth at low cost.

If we look back, however, we can see that today's trend in investment in new technology is being governed by demand, but demand in terms of the ability to give payback on operations, rather than the original sunk cost. Parts of the industry may be indulging in creation of scarcity rents to drive up prices when there is a long distance bandwidth glut.

Figure 2.11. **Capacity projection for Wave Division Multiplexing (WDM) fibre, and Optical fibre Time Tivision Multiplexing (OTDM)**



Source: EC IST Optimist, IST Zabreb, mai 2003 (*http://22.ist.optimist.org*), optical networking projects EC DG INfo Soc, *http:/intecweb.intec.ugent.be/list-oprimist/pdf/trends/TERENA_2003/sld023.htm*.

For instance, in the United States, a spending spree on long distance fibre between 1997 and 2000 was caused by a combination of the market opening effect of the 1996 Telecommunications Act and a surplus of investment capital, with dozens of new fibre-optic networks being installed. The oversupply of fibre optic cable is mostly limited to the long-distance networks, which were built first. Thus commercial prices of fibre optic long distance are difficult to pin down currently both because prices are still falling steeply due to over-supply and because the developments outlined above are reducing the new cost per channel. One way to judge price deflation is to look at the wholesale market, in a developed country such as the United States. According to RateXchange in 2001,[56] a US electronic broker for telecommunications carriers to trade bandwidth capacity wholesale, a connection running at 155 Mbps from Los Angeles to New York cost about USD 45 000 a month in October 2000. That price fell to USD 35 000 in March 2001 but was expected to be USD 2 450 in January 2002 for the new generation of equipment. A 155 Mbps connection in 2001 could handle about 42 million minutes of calls per month. Today's optical technology can increase that capacity at least ten times.

The key point is that the launch equipment may be the only part of the network that has to be changed; if it is of a fairly recent technology, the actual fibre stays the same and there are thousands of strands in the ground. By this approach, in 2002/03, US carriers upgraded many long-distance networks to 10 Gbps, from 2.5 Gbps. The US infrastructure spend before 2000 shows the order of (over) expansion in fibre capacity today and possibly for some years to come. Capital equipment spending by US telecommunications carriers grew 36% from 1998 to USD 77.1 billion in 1999, and another 35% in 2000.[57] But spending fell in 2001 by some 13% from the previous year and then reduced to some USD 74 billion by 2003, a fall of about 29%. The drop in spending means carriers will spend less to use their networks, because it costs more to activate the networks than to leave them inactive, as "dark fibre", *i.e.* unlit. Thus the amount of fibre not being used may be increasing, to shore up prices, while new infrastructure investments stall.

Of course there are other markets than the wholesale carrier and Internet ISP markets. Private leased lines in international and transatlantic markets have been another profitable source of revenues. Large profits were being made on international leased circuits before the dotcom crash in 2000/01. To give one example,[58] a 2 Mbps circuit from Switzerland to the United States was retailing to end-users at about USD 500 000 per year in 1997, while the operating consortium's purchase price, discounted over five years and including annual maintenance and operation, represented only some USD 60 000 per year. Even allowing for the terrestrial circuits and for operations, overheads and profits, this was a high margin. Another example, for 2 Mbps circuits on the US-Australia route indicated typical end-user charges were USD 98 000 per month, while the

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costs incurred by consortium members to provide such circuits were estimated to amount to less than USD 13 000 per month.[59] However by using the new security and traffic discrimination resources in IPv6 for the Internet, corporate VPNs can be hosted on the expanding Internet infrastructure, which still has spare capacity, so that the attractiveness of literal control of physical resources – leased lines – is reducing in favour of hosted shared services, in which the major ISPs can use their peering agreements to extend their geographic reach.

In summary what we see is expanding demand but faster expansion in capacity, using replacement technology, not new construction, and the current real capacity is unknown due to over-investment in some areas of the United States and possibly Europe. Installed fibre can be quickly and comparatively cheaply upgraded by perhaps ten times (or more) in capacity with each new generation of WDM. In consequence, while overall bandwidth demand soars with broadband services and Internet access for media content, we can expect major long distance infrastructure capacity expansion, but not wholesale renewal with extra fibre.

Turning to alternatives for long distance to 2030, there seems to be some potential in power line carriers, but this is usually interpreted, for long distance, as embedded fibre inside earth or perhaps HV cables.

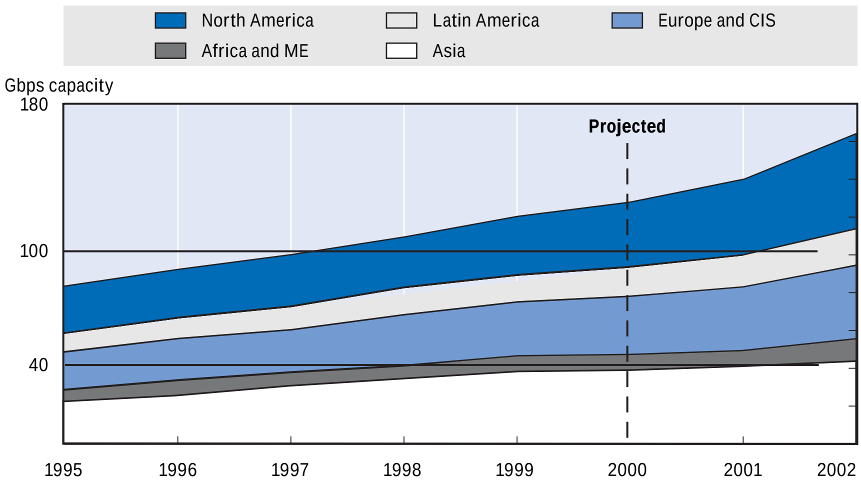
As noted, the future of satellites does not indicate a significant switch to their use for long distance traffic. Their capacity historically is quite low (see Figure 2.12) so that, without a large change in technology and orbits, they do not seem to be a major contender for infrastructures for the future. They will have a part to play, for instance in combination with mobile, for content broadcast, especially of non-isochronous traffic:

Alternative Wireless Technologies (AWTs) in the local loop

For cost and rollout reasons, as well as the bandwidth that AWTs can offer, there is strong potential for AWT mobile to leapfrog fixed line broadband communications and mobile cellular. Recent case studies on the first AWT implementations indicate they may bring lower costs to mobile radio communications, although large-scale implementations of the leading contender, WiMax, are still to be deployed. One large case study with proprietary Flash OFDM (from Flarion, a spin-off of Bell Labs, now owned by Qualcomm) has shown up to 80% cost savings over an equivalent coverage by a conventional mobile cellular network, which could only offer narrowband capabilities for voice and data.[60]

Generally, AWT networks demand a much lower infrastructure cost base than 2G or 3G mobile in that the equipment is based on data communications experience with wireless hubs for WiFi. They may avoid special sites, by placing the transceiver units on outside walls, lampposts, etc., while local power supply

Figure 2.12. **Growth in satellite communication capacity**



Note: Chart assumes that a pair of 36-MHz equivalent transponders will yield approximately 40 Mbps transmission capacity. Transponder inventory refers to available capacity in orbit (minus satellites retired) or already under construction in March 2000.

Source: RAND 2000, *Submarine cable infrastructure*, and Euroconsult.

requirements may be lower than cellular if lower output power is transmitted. They may even be autonomous from local power supplies, as solar powered transceivers (or "access points") have arrived. The propagation performance, as ever, sets the density of access points required, but this propagation can be further than with conventional mobile cells, for lower density. As support infrastructure demand is in general much lighter, AWT networks for Internet access, with VoIP, are springing up in an *ad hoc*, guerrilla fashion across Europe and especially the United States. In the latter case, this is often in a non-operator centric situation, in that they are financed, built and operated by the local municipality as shown below (while raising ire and opposition from the incumbents RBOC, who have moved to have them banned in many US cities).

Naturally these technologies put pressure on the spectrum apparently available. Using spread spectrum techniques for bandwidth sharing and the cognitive radio (CR) techniques, which adapt to other users, they promise to bring far more efficient use of the spectrum. The concepts of a larger "commons" in spectrum in the form of more or wider unlicensed bands is under debate in the EU. Meanwhile the United States and the United Kingdom currently prefer a market driven approach, perhaps for reasons of financial gain for government,[61] despite the gathering forces from the computing and data communications world who have demonstrated with WiFi the success of the data communications/ Internet model of an unlicensed, unregulated spectrum infrastructure.

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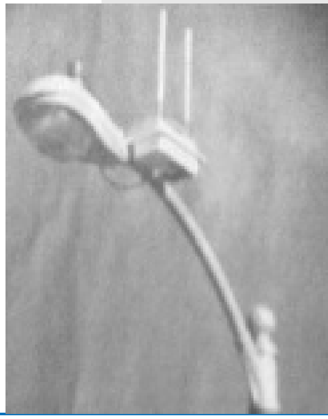
Figure 2.13. **AWTS offer lower infrastructure cost**



Wireless transceiver and router on lamp post, for mesh WiFi network in Chaska, Minn., USA using Tropos MetroMesh equipment with KarlNet point to multipoint radio backhaul and OSS from Pronto Networks, for billing, etc. operated by municipality.

Source: Financial Times, 15 June 2005, IT Review, P. Taylor, Freedom to roam makes new pioneers of Minnesotans.

Firetide and Transnumeric Deploy WiFi Mesh Network in Gordes, France *New Technology for Community* SEPT. 12 2005- **Firetide, Inc., together with its French partners Transnumeric and Xavier Dalloz Consulting, today announced deployment of a WiFi mesh network for the rural village of Gordes, in the Luberon, France with high speed alternatives to DSL in rural areas. Internet access is shared through access points connected to a Firetide wireless mesh network in an area covering a square kilometer. "The Gordes deployment is part of French Prime Minister Dominique de Villepin's call for projects providing high-speed access and services for the territories." – Alain Ducass, Chief, Digital Country Planning Office of the Prime Minister.** Press release

Clearwire offers WiMax in Belgium

- **US Broadband wireless provider Clearwire – commercial WiMax network in Belgium.**
- **Initially deployed kit from NextNet Wireless with coverage of 60 per cent of Brussels and about 75 per cent of Mont St. Guibert.**
- **Number of subscribers not released. Plans to expand the service throughout Belgium.**
- **Uses pre-WiMax equipment in the 3.5GHz spectrum band and 40 base stations deployed. 2 different data packages offered-**
- **downlink speeds up to 1 Mbps and uplink speeds 256 Kbps,**
- **downlink speeds of 3 Mbps and 512 Kbps on the uplink.**
- **Monthly tariffs €28.99 for slower package and €78.99 for the faster. Later this year it will use NextNet WiMax standard products.**

Source: Fierce WiFi 10 AUGUST 2005.

Moreover the new technologies can offer mesh networking through intelligent adaptive front end with software defined radio for the air interface and so can extend range, and also cope with the highest densities of users by employing alternative routing via relays through hops to adjacent handsets. In effect they can form *ad hoc* networks, as necessary without a fixed infrastructure element present, as shown in Figure 2.15.

Future telecommunications infrastructures for the coming decades

In consequence it is possible to see the progressive arrival of a new model of infrastructure, heavily influenced by the requirements of the low-cost demands, from developing countries seeking more "bits per buck" for their billions of people in the under USD 3 000 per year income bracket. It is based on the superior accessibility of mobile and the new low cost of AWTs for mobile, especially in mesh networking, and the falling cost per bit carried on

Figure 2.14. **Radio prolongation of wired access point**

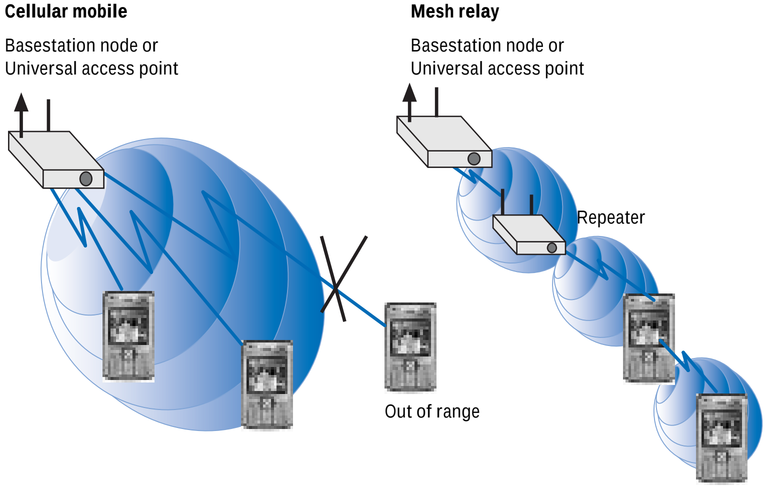
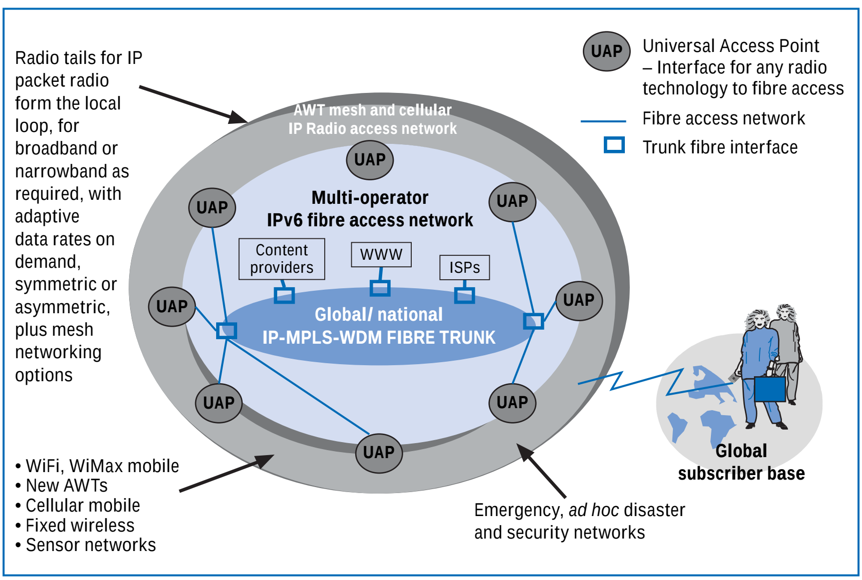


Figure 2.15. **The future fibre-radio composite infrastructure – a simplified network**



WDM fibre for long distance, to form a two-level IP model, reminiscent of BT's 21CN architecture, but simplifying local loop access down to AWTs with mobile wideband and broadband capabilities.

Its architecture is based on robust forms of the IP protocol end-to-end for isochronous media and bursty data transfers, with IPv6 or its descendants beyond 2020. It is designed from the perspective of the data communications world, and the support of packet services such as VoIP and content streaming.

Such a simple architecture would gradually form over the next 10-20 years by progressive refinements of the complicated nest of existing standards and networks. Thus for both economic and technical reasons it may be deployed first in the developing world, as there are less legacy networks and protective regulation with vested interest in the commercial/technical *status quo,* whose power should not be underestimated.[62] The new efficiencies of such a structure will tend to seep back into the OECD communities' infrastructures.

Perhaps this might occur quickly if competition forces openness, although the prolonged continuance of existing networks can be expected for commercial/political reasons, such as the 20 years of 3G licences still to run in many OECD countries. A number of OECD incumbents (such as France Telecom and Telefonica) with mobile licences and ISPs are integrating these activities back into the main company – the purpose is to offer a single seamless service to customers using NGN linked to the operator's mobile technologies. However, the costs of 3G licences have been so large for some major operators that they cannot be simply written off as a sunk cost. Their market reputation, as well as mandates from the financing holding companies in certain cases, plus further 3G network investments such as HSPDA could force share prices to suffer more than their boards can permit. They are thus destined to battle on with 3G technology and expensive enhancements such as IMS (IP Multimedia Subsystem, needed to build an all IP path). In such circumstances, the major OECD 3G licence holders are quite constrained from moving on to newer mobile technology.

Consequently, new wireless technologies are far more likely to emerge in developing economies and then seep back to OECD economies. The result may be parallel operation of two infrastructure models globally for at least a decade: a previous OECD model of mixed long distance carrier standards for trunk networking with a legacy of wireline in broadband DSL and CATV cable in the local loop, and at the same time, the simpler two level radio access/fibre long distance model slowly spreading across the world.

A notable feature of the architecture is the Universal Access Point (UAP) which interfaces the various radio technologies; UAPs will demand much R&D to cope with all network types.

New architectures for robustness in emergency

One requirement for the new infrastructure is the need for it to fill new roles. Perhaps the major challenge that the infrastructure must respond to is a heightened level of threat, from natural disasters associated with global warming, with increased risks expected over the next century[63] as well as man-made catastrophes and attacks.[64] What is needed is a wide range of features useful in a disaster for the emergency services, principally:

- Ubiquity and pervasiveness – inside, outside, at the level of a person, a sensor, a network, a city, a suburb, or a region – with a network technology and topology suited to each case's requirements.
- Reliability – through redundancy in coverage, with overlapping functions and range.
- Disaster recovery through self-healing.
- Instant set-up – can be added to, or installed on demand, far faster than conventional networks.
- Independent of any fixed infrastructure if required.
- Low cost compared to current fixed and cellular, as many disasters will be in the developing world.
- High bandwidth (compared to cellular) for far more functions, especially image and video.

The answer may be a compound architecture of different AWT networks in a hierarchy of civil networks to overlap functions and coverage for redundancy. The security and emergency advantages of *ad hoc* deployment make AWTs attractive as the basis, because they offer all of the requirements featured above. The various networks in the hierarchy should inter-operate for applications requiring input from the different data flows on each network. To become self-healing the set of networks may also be self-organising. During the September 2005 Hurricane Katrina disaster, the only voice communication possible from the US President's plane when in the air to the Mayor of New Orleans was via a WiFi Internet connection still operating in the city – this key conversation was carried via a VoIP service provider.[65]

A recent EC/JRC/IPTS study on AWTs has proposed one form of combination of networks to create a security infrastructure with *ad hoc* capabilities for set up and topology and the overview of this compound architecture of different AWT networks is shown in Figure 2.16.[66]

Other local loop and long distance infrastructure technologies

Possible use of low earth orbit satellite system (LEOs): LEOs have failed before in mobile satellite services (MSS) ventures such as Iridium, Teledesic, etc. A new second generation is planned but appears just as likely to fail for the same reasons – demand against system cost. However a new launch model with hybrid oxygenation for flight propulsion systems for conventional take-off and landing (HOTOL) could make the difference for a third generation of LEO by 2015. Proposals for MSS are based on putting massive shoals of

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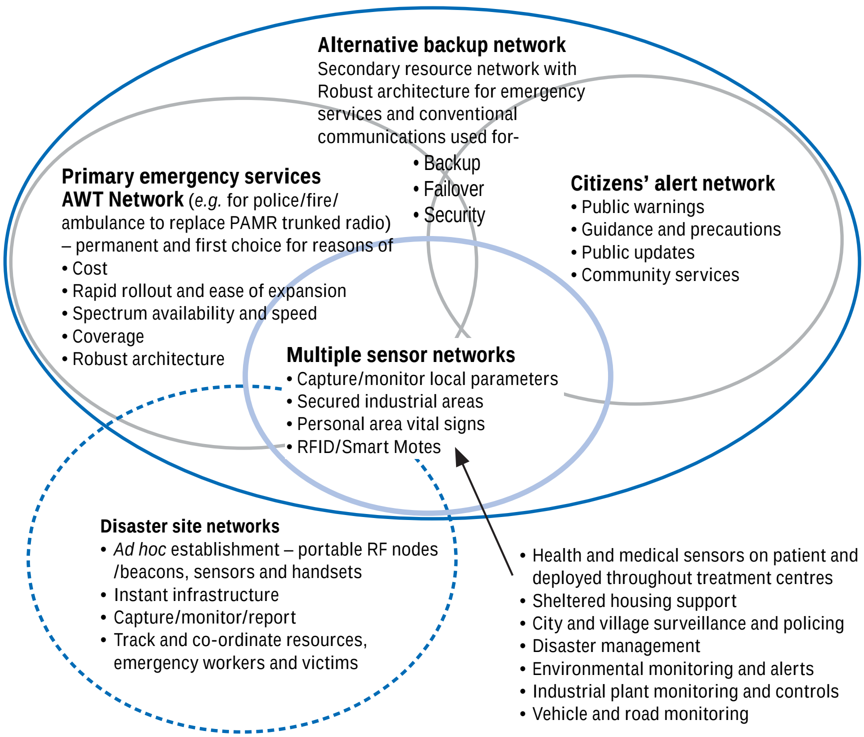
Figure 2.16. **A compound network for security – suggested integration of multiple AWT networks into a single security resource**



Source: Mapping European Wireless Trends and drivers EC/IPTS/JRC, September 2005, to be published.

micro-satellites into low orbit space, if a lower cost of payload in space per kg can be achieved, to give reduced signal power in the handset and to squeeze up-link and down-link latencies to a minimum. Handsets might use MIMO (multiple input/multiple output) solid state directional antennae technology to track multiple micro-satellites as they come over the horizon. For in-building communications, repeater hubs to assure signal propagation inside the building would be required. The shoal's adaptive structure could also carry and switch the long distance traffic. LEOs are an unlikely infrastructure component.

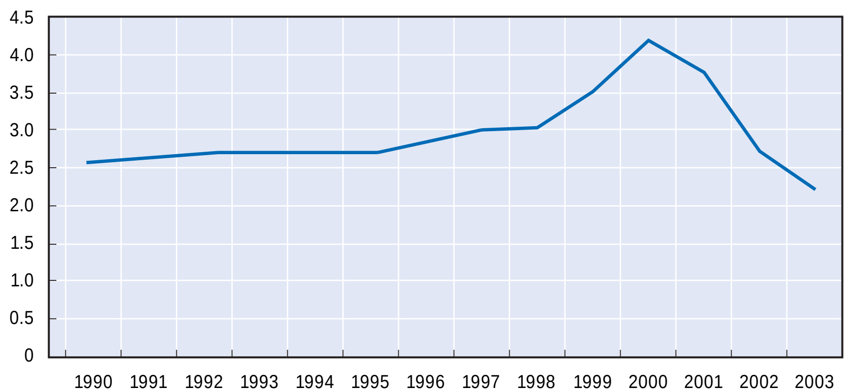
Possible use of high altitude long endurance systems (HALES): These systems propose the use of circling aircraft high enough in the stratosphere so that there is no weather perturbation – as a (fairly exotic) regional or urban mobile solution that has been mooted for some ten years. HALES require very reliable flight operations (perhaps solar powered) but could have high-density urban applications. Although full systems are unlikely, HALES could have emergency disaster area applications, offering instant infrastructure deployment, especially for big cities, by replacing destroyed cellular mobile, or more easily, WiFi and WiMax networks. Signal identification from handsets at low power designed for terrestrial networking would be a challenge but not insoluble.

Possible use power line carrier (PLC): Systems employing signalling to home/ office infrastructure has been around since the mainsborne signalling projects of the United States and others including the United Kingdom's DTI initiative in the 1970s. So far little has been achieved. Problems of noise, interference with attached appliances, including military equipment and the cost of the premises equipment have kept PLC back. Without enormous progress in signal propagation and noise processing algorithms, there seems to be little future for a local loop technology and less as long distance trunk technology over high voltage networks (except via fibre optics inside the national distribution power lines which has been proposed as a bypass technology).

The level of investment – impacts of the new infrastructure model

Over the past decade telecommunications spending has varied according to the economic conditions with a boom in the mid 1990s and then a reduction, from the "telecoms bust" from 2000 onwards, as shown below.

Figure 2.17. **OECD average of public telecommunication investment as a percentage of gross fixed capital formation (GFCF) 1990-2003**



Source: OECD Communications Outlook, 2005 (1990 1996 are 3 year averaged figures).

Thus, although the number of subscribers to all telecommunications services grew at the rate of over 225 million per year over 2000-03, as shown in the graph below, it accelerated to over 320 million per year in 2004-05 as mobile subscribers jumped by some 300 million.[67] Absolute global spend on infrastructure over 2000-03 continued to climb as shown on the left side of the figure, while growth in capex oscillated with economic conditions at around 4% to 5% per annum, as shown in the graph on the right.

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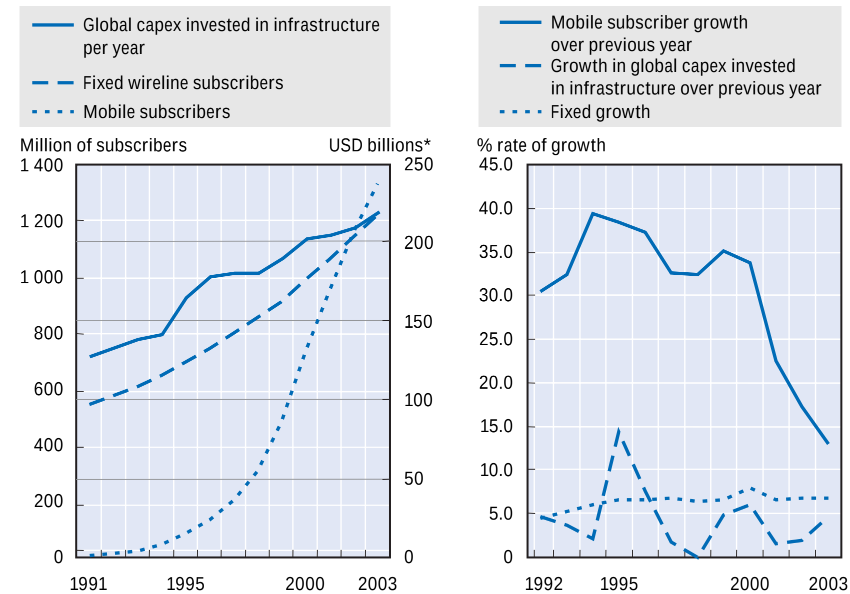
Figure 2.18. **Growth of subscribers**

Growth of subscribers worldwide 1991-2003 fixed and mobile against infrastructure investment (ITU) – the trend is for infrastructure spend to rise – but not nearly as fast as the number of new users, especially in mobile

Worldwide growth rates as % growth over previous year for fixed and mobile subscribers and capex investments, 1992-2003. The trend is for mobile growth to slow as the initial phase, of filling capacity in the OECD area, ends as those markets become saturated, while fixed wireline nears saturation.



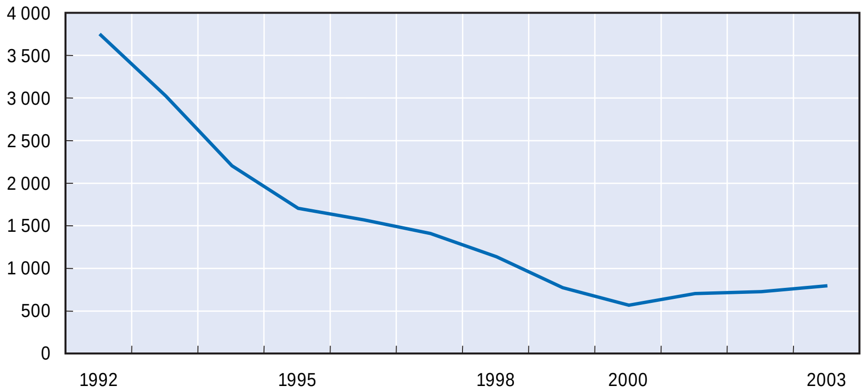
* Current prices and exchange rate.
Source: ITU world telecommunications indicators database 2002.

Source: SCF Associates, derived from ITU world telecommunications indicators database 2002.

However, since 1992, the capex per new subscriber added to the networks, both fixed and global, has fallen substantially, by over 80% by 2000, as shown in the figure below. It is only just starting to rise again, under the influence of the new generation of mobile networks, the 3G UMTS, which have (far) higher costs than 2G, and also rollout of HFC broadband networks, although their impact on spend is limited by the numbers taking these new services. Thus, whatever the absolute annual spend, the trend, derived from the latest figures available from the ITU, is generally to ever cheaper telecommunications networks per subscriber added as the subscriber base expands, as illustrated in Figure 2.19.

This is the natural result of falling equipment prices and new technologies for mobile radio. But what of the future? In the short term, level spending with rapid rollout is likely, followed by a decline in spending as the total number of subscribers expands, up to around 2025. The cost per subscriber should fall

Figure 2.19. **The key trend is to cheaper infrastructures – Capex per new subscriber[1] in kUSD 1992-2003**



1. Calculated as capex spend in previous year to create new subscribers in current year.

Source: derived from ITU world telecommunications indicators database 2002.

rapidly from, say, 2015 as the new lightweight infrastructure assures a continued rollout, now into the unsaturated poorer sectors of the developing regions. Taking the figures used previously of numbers of subscribers and spend per subscriber required for take-up by using the Dupuit curves and the perception of freeness points, a simple model of infrastructure costs per subscriber emerges (see Table 2.15).

Of this infrastructure spend, on first approximate estimates, we would expect that the OECD accounts for around 60% of total spend up to 2010 as their next generation networks are rolled out, spend which then diminishes while the NICs rapidly become the areas of the major spend thereafter with over 50% of investments in the major investment period after 2015, when OECD is saturated. Within the portion spent in the NICs, the major tranche of spend would be expected in China and India to 2025, with just these two economies accounting for around 50% of the developing world's portion of infrastructure spend after 2010 but perhaps easing off after 2020 or 2025 in proportional spend as the primary needs in their major equipping phase are met. By 2030 we would expect that today's developing world will take probably at least 50% of spend so that the OECD community would account for an equivalent level of spend, but possibly less. These estimates are based on assumptions of spend per subscriber being far less in the NICs, but not necessarily far lower in capacity for throughput or potential for rich services.

Note that the total infrastructure spend in billion USD in the table above reaches a maximum in 2010 as demand for infrastructure takes off, to serve an estimated 4.5 billion users (fixed and mobile). In subsequent years to 2030, the

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Table 2.15. **Projected infrastructure capex per new subscriber and total infrastructure spend globally**

End of year	2005	2010	2015	2020	2025	2030
Capex/new subscriber, USD						
OECD fixed	1 000	950	500	300	200	160
Non-OECD fixed	400	350	250	180	160	110
Mobile OECD	700	650	300	200	160	80
Non-OECD Mobile	300	250	150	120	80	50
Blended OECD/non-OECD capex per new subscriber, fixed and mobile, USD	600	550	300	200	150	100
Mobile subscribers, billions	1.8	3	4	5	5.2	5.3
Fixed wireline subscribers, billions	1.3	1.5	1.4	1.3	1.2	1.2
Total number of subscribers, mobile and fixed, in billions	**3.1**	**4.5**	**5.4**	**6.3**	**6.4**	**6.5**
Subscribers added in that year, billions, average over the 5 years	0.3	0.3	0.2	0.2	0.02	0.02
Estimated proportion (% age) new subscribers that are non-OECD	70	80	90	95	95	95
Estimated proportion of non-OECD new subs that are mobile, % age	90	95	95	98	98	98
Proportion of total new subscribers that are mobile and non-OECD, %	63	76	86	93	93	93
New infrastructure spend per year, billion USD	**180**	**154**	**54**	**36**	**3**	**2**
New spend on non-OECD mobile, BN$	56.70	53.20	23.09	20.11	1.49	0.93
New spend on non-OECD fixed, BN$	12.00	4.90	2.25	0.65	0.06	0.04
Proportion of new infrastructure spend per year, that is non-OECD, %	38	38	47	58	52	49
Installed base factors						
Installed base net value[1] billion USD calculated as number of subscribers times capex per user, with capex averaged over previous 5 years	3 160	3 938	3 945	3 575	1 120	812.5
Infrastructure maintenance and renewal spend at 15% of installed base value, billions USD	474	591	592	536	168	122
Total infrastructure spend in that year, billions USD	654	745	646	572	171	124
NON-OECD proportion[2] of total infrastructure spend in that year, %	38	38	47	58	52	49
OECD proportion[2] of total infrastructure spend in that year, %	62	62	53	42	48	51

Note: This is a highly approximate model with many assumptions and first estimates. (To create a reliable model would be a medium/large project in itself.)

N.B.: Model assumes a simple incremental forward investment over 12 month cycle of capex spent in previous year adds this year's subscribers.

1. Includes inflator factor for historic levels of more expensive legacy OECD infrastructure of $1 500 per fixed line (broadband and PSTN) and $1 000 mobile, for 2 billion subscribers (as 1 billion subscribers each for mobile and fixed) for 2005-20 and assuming average of previous and current capex per new user over last 5 years.
2. Assume new subscribers ratio is quickly reflected in the installed base value so proportion of infrastructure maintenance of installed base for non-OECD has same values each year.

total investment reduces. This is due to the impacts of technology costs, which are expected to reduce sharply with the effects of both lower-cost yet enhanced technology but at volume pricing, the two factors having a net deflationary impact over 20 years of some 80% of gross costs (equivalent to a non-compound, simple linear drop of around 4% per annum); those costs are comprised of renewal and maintenance of existing plus new build investment. New build investment itself is expected to drop in magnitude as saturation of the user population is reached and so the major portion of investment is taken up with renewals and support maintenance. Note that this investment estimate table is highly debateable, being given over 25 years, with many assumptions for the dependent variables being open to challenge, and so is at best only an outline indication of investment patterns.

Migration to a new infrastructure model

It would be naïve to imagine that dramatic change in infrastructure will happen globally as a big bang, or that it will happen very soon. Introduction will always be progressive, the new interworking with the existing. It may be at least a decade, or perhaps two, before such large changes could be effected. It may be many years before any move towards new infrastructure is even made, depending on the region. Vested interests in the *status quo* in telecommunications infrastructures have powerful arguments to protect their investments when speaking to government and regulators.

However there are regions in which it could happen far faster than others. First movers will be those where the investment is available and the current operators are weak while the infrastructure is not deeply entrenched in the fabric of the economy. This favours those having the worst infrastructure today but the available capital, if the return on investment can be justified by strengthened telecommunications. Let us examine the OECD regions and the large developing economies, in order of probability of migration:

- The obvious candidate for a first mover is thus India, not China. In China, infrastructure is further advanced – it will be less likely to change very quickly. In India, the nature of the telecommunications infrastructure and the ITC industry structure implies large changes could happen more quickly, perhaps piecemeal, backed by poorer local state governments wishing to catch up, and also central government.
- China and especially South Korea are already starting with tentative steps in this direction and Korea's current 5-year plan (IT 839) could be diverted in this direction as IPv6 working is already in the plan. However the inertia of vested interests and the satisfaction with the current course will delay moves to a new infrastructure. In China perhaps after 2012, large-scale new developments could begin as the rural areas are upgraded to match the coastal regions and there is less investment to amortise.

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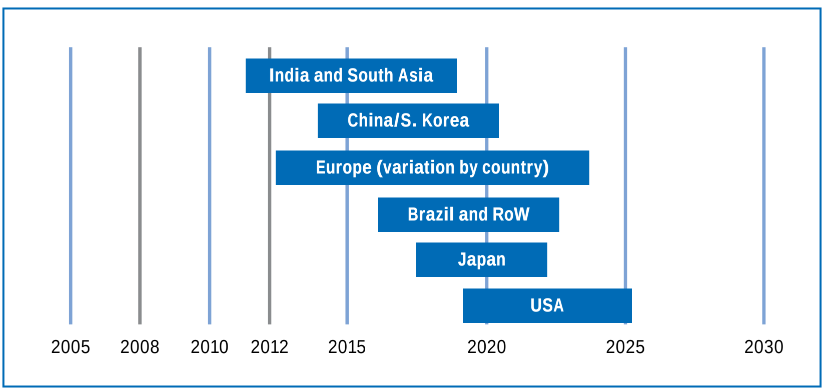
- Unless Brazil takes the advantages of low-cost telecommunications more seriously, the vested interests in the current infrastructure are likely to prolong its life, as it is serving its purpose fairly well, supporting reasonable GDP expansion with manufacturing. No strong reasons to move are apparent.
- In Europe there is a highly mixed picture. BT in the United Kingdom could move to this model early (before 2011) if it changes its local loop technology plans, but this is quite unlikely. More likely are moves by the most ICT-aggressive new entrants to the EU, the Baltic or Balkan states such as Lithuania or Slovenia. France and Germany are more likely to consider migration a decade later, as current infrastructure is good and price competition can be held off until current investments have been amortised.
- The United States and Japan have fairly modern infrastructures but the United States's has piecemeal quality and bandwidth. However vested interests in both countries are large and powerful, so the change to a new infrastructure could only come from moves by the media and cable companies and the ISPs.

One possible illustration of the migration phase of each region is shown below, as a potential example.

Figure 2.20. **Conversion to all IP infrastructure of fibre and radio access**



5. Implications for business models

This section examines implications (financial in particular) for public or private construction of infrastructures, risk sharing, and public/private partnerships. In particular we look at the viability and sustainability of current business models in fixed line and mobile telephony/broadband of new infrastructure on current business models.

Traditional fixed line operator models

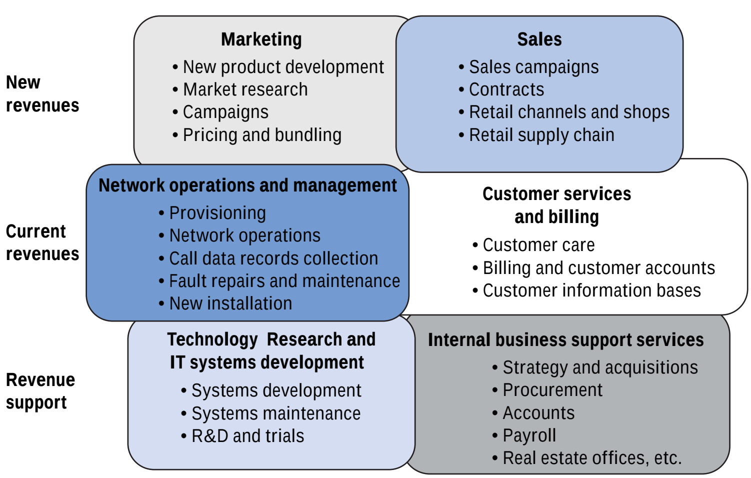
Traditionally, business models in the telecommunications industry have been founded on the premise that it is a highly regulated industry with controlled entry. Historically, the regulated but protected monopoly position has produced the powerful incumbent operator in each country, especially where the regulator *was* effectively the national operator. This has been justified as necessary for safe investment of historically relatively large sums of public funding in infrastructure (up to the 1960s, some 2% of GDP), whose deployment may not have been seen as secure by the state without the monopoly position. With deregulation, this privileged market position has still left incumbents with protection of their business model based on two factors:

- Use of the sunk cost of the network as a barrier to entry of others – the cost of infrastructure competition.
- Ownership of the customer through ownership of the local loop.

A third factor is perhaps leveraging of established political position to build resistance to deregulation and the entry of new players with destruction of their market power once they have entered. The most successful example of this has been the resistance to unbundling the local loop, preventing others from "owning the customer", the second factor, while also preserving the first protective factor of complete infrastructure ownership.

In analysing the business model, it is useful to look at the business processes and business divisions. The telecommunications operator business process map has several notable features as summarised below.

Figure 2.21. **Example of major business divisions in a telecommunications operator and the core business processes, some of which may run across several areas (*e.g.* billing)**



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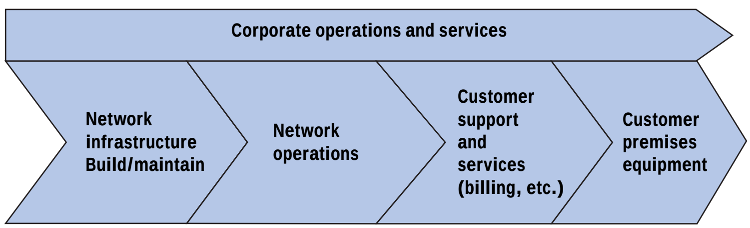
These major business divisions are common to most operators. The value chain for the telecommunications operator is marked by leveraging capital invested in the network infrastructure to provide services to the subscriber base, traditionally at regulated tariffs, on down to sales and support of customer premises equipment. With the arrival in most countries of some form of market competition, tariffs have (to variable extents) been free to be set by the market, as bulk resellers and other competitors enter and regulatory protection shrinks. Effectively, the traditional value chain has been as shown as below.

Figure 2.22. **Traditional telecommunications operator value chain – a generic model**



In this model, the key to revenue generation is the number of call minutes and keeping them as high as possible while maintaining tariffs. The key to margins, once the capital invested in the network is being written off at a sustainable rate compatible with revenues, is in other parts of the cost base, notably personnel, and the number of staff per 1 000 lines is a key performance indicator.

Mobile cellular radio operators

The differences in business model for mobile cellular operators are not that significant at a business process level but premises equipment becomes handsets, and the local loop is the radio access network. The major cost of entry is the mobile infrastructure, which includes the cost, not just of a core network behind the radio access network, but also the acquisition and/or rent of suitable sites for cellular basestations.

As might be expected, infrastructure costs demand enormous start-up capex. But historically, 2G mobile tends to have much faster payback than fixed line networks as the customer base has built up far more quickly. This is due to the enhanced accessibility, provided suitable pricing and payment plans are in place (especially the pre-paid card in lower disposable income countries, such as Portugal and Italy) and handset pricing is optimised through subsidisation or low cost units. This has not been the experience with 3G infrastructures however.[68]

A further difference to the fixed line operation is the radio technology. Expenditure on more intense and capable customer care services is necessary due to retail handset sales and their provisioning over the air. The major customer care cost is in dealing with problems of the network quality of service and handset failures. Maintaining connection (and reputation) is crucial to obtaining revenues. Negligence, high quality customer care and basic network quality bites into margins. Margins today thus depend on two factors:

- Quality of network and handsets, and the subsequent levels and quality of customer care.
- Roaming and termination charges, which are often inflated compared to the costs of provision of these services, at levels perhaps several times that of normal tariffs.

Generally mobile operations are more recent and have fewer staff per customer than the legacy operations of fixed line operators. For instance in comparing two operators in a recent acquisition it is notable that the target acquisition (O_2, a mobile company) had 24.6 million customers and 15 000 employees (note lines are taken as customers for mobile, in terms of the number of customer cards, or SIM cards), *i.e.* 1 640 customers/employee. In contrast, the acquirer (Telefonica, a mix of largely fixed and some mobile) had quite different ratios with 145 million customers and 173 000 employees, *i.e.* 838 customers per employee.[69]

Telecommunications equipment supplier business models

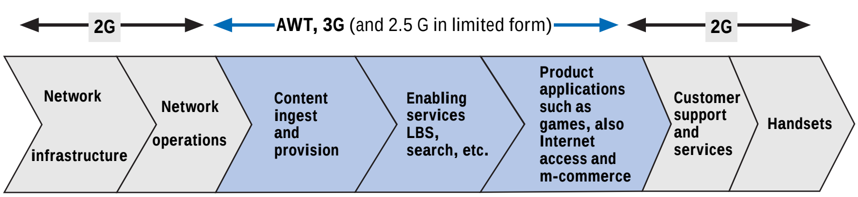
Traditional supplier models have been based on a protective tied or close relation to a local national incumbent. The model is based on initial large R&D expenses being paid for by sales to the local incumbent(s) which then leads to worldwide sales, at lower costs, but increasing margins per unit sold in volume production. Further continued revenue generation is based on manufacturing for renewal and upgrade for the tied market, the infrastructure of the national operator, while again reselling the same refreshed product globally, either to developing countries or where infrastructure equipment competition is possible. The traditional model is followed to a varying extent in most OECD countries, notably Germany, France, Japan, Sweden, Korea, Italy and China, with the exceptions being the United Kingdom and to a limited extent, the United States. An example of the extreme necessity of this dependence is the failure of the United Kingdom company, Marconi in October 2005, with its forced sale to Ericsson when it failed to win a GBP 10 billion contract for new infrastructure with BT, the nationally dominant fixed line operator. Effectively it was undercut on costs in a free market environment, by new suppliers from the NICs with a far lower cost base for R&D and more advanced technology (for end-to-end packet switching) such as Huawei and ZTE from China.

New operator models challenge the current business models

The previous section highlighted the fall in infrastructure costs per subscriber (fixed and mobile) over the past decade and the likelihood of this continuing into the future. Far lower costs of infrastructure and faster rollout mean lower costs of entry and also less time needed to obtain payback on investments. Consequently competition will be far greater. But also we can expect many shakeouts, as the market becomes saturated and margins on offerings become leaner. The logical consequence may be global consolidation, down to a few very large bulk carriers by 2030. In these circumstances regulation will be necessary to ensure competition and protect against restrictive practices and collaborative agreements.

The new infrastructure based on data communications principles will drive business models more toward the data and computing industry and away from telecommunications industry models of incumbent market dominators or oligopolies. Future business models will be much lower and with simpler operational processes. Moreover we can expect to see content provision appearing in the traditional value chain, as shown below.

Figure 2.23. **There is a new mobile services operational chain in 3G cellular, in AWTs such as WiFi and in a more limited form, in 2.5G**



In such a scenario, regulation as regards business models and infrastructure will be more towards keeping infrastructure open and secure as well as ensuring competition. Eventually we may see a trend for business models to adapt as regulation becomes more regional (*e.g.* an EU regulator). Also at the same time there may be a trend towards global regulation, under WTO pressures on trade in services, which will converge media with telecommunications. A global regulator covering infrastructure operation may evolve by 2030, setting rules in a harmonised fashion, *e.g.* for security, safety and privacy but also for termination and interconnect charges and competition.

However the major change for operators will be in accommodating global competition and its inevitable pressures towards cost-based pricing. Operators must be structured for far lower tariffs ("near-zero") and so will tend be lean compared to today's business models of staffing levels and operational expenses such as IT systems, especially for billing and customer care.

Infrastructure competition may disappear as mobile and fixed interwork into converged operations which might become the norm, as explored in the previous section on infrastructure shape, and so the idea that radio-based communications will remain separately operated may not survive.

In summary future infrastructure points to several new types of player and accompanying business models:

- Carriage only – more ISP like – that is flat charging for many low-paying customers.
- Wholesale only – the operator model is to transport traffic (largely mobile) for other operators – using an IP transport network such as BT's in 21CN.
- Services only, using any carrier network, with media content sales as the main offering, perhaps mixed with specialist handset sales, optimised for the content (the i-Pod model).
- Mixed services and infrastructure ownership – use of services to subsidise infrastructure and low costs per session – so the operator may own some content and/or be a content aggregator but may also resell access and the delivery platform for its customer base to partner content owners (an extension of the i-mode model from DoCoMo). It may also enable access to any suitably purposed Internet site.
- A variation on the above is the entry of the major media players, be they from cable TV or from content providers, or the ISP community such as Google, eBay, AOL or Yahoo. Starting with mobile access and free IP calling (VoIP), they will offer content and communications, probably leveraging an all-IP infrastructure either in partnership with infrastructure owners or via the freedoms of Internet access. Their business model can be detached from subscriber revenues, but based on advertising and forms of e-business commissions, such as eBay.
- New models from non-operator centric organisations – *e.g.* municipalities, based on stimulating the local economy, so there may be no direct revenue gathering, only indirectly through local taxes.

Two factors distinguish these future business models from the past:

- The key to revenue generation will be to maximise the number of very low paying customers, instead of the maximum ARPU per customer.[70]
- The key to margins will be based on successfully creating lean operations, for cost-based pricing – *i.e.* understanding the cost structure for very small margins per customer. This is a major challenge for conventional operators.

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The coming supplier business models

With the evolution of the infrastructure, the supplier business models will change towards:

Models within the software industry – but with use of open source software as foundation.

Far more emphasis on design and consumers with socioeconomic studies of new usages, picking up early demands/trends/fashions and feeding them into far more formalised innovation and R&D business processes, as the handset manufacturers (Motorola and Samsung particularly) have been starting to do. The move to simplicity and ease of use will be the theme for coming design as consumers are increasingly baffled by the complexity of a richer offer of services (the Korean VCR syndrome).

Very low cost manufacturing – in response to the above, to produce simple to use, sophisticated networks and devises for a mass market.

Conclusion

The conclusion is fairly stark. New infrastructures will accompany new business models. They will tend to make the current business models untenable so current operators must adapt, or fail.

6. Telecommunications substitution and secondary effects

Identifying telecommunications mechanisms

Telecommunications has the potential to substitute for other infrastructure elements using suitably priced telecommunications services. For instance, videoconferencing can substitute for travel to a face-to-face meeting. This section explores the significance of such substitutions for investments in other infrastructure types, and the degree to which this might happen in OECD countries and in the NICs by 2030.

The section also explores secondary effects of telecommunication usage and substitution on other types of infrastructure. For instance, telecommunications could stimulate telework and migration to rural areas, which would produce secondary effects on other infrastructure such as electricity distribution.

Overall, substitution has the potential to bring economies in budgetary and efficiency terms in two cases:

A) Where telecommunications may substitute for physical infrastructure:

- Reduce usage and need for private and public transport.
- Lower demand for roads expansion.
- Reduce demand for airports, ground infrastructure, flights and ATC expansion.

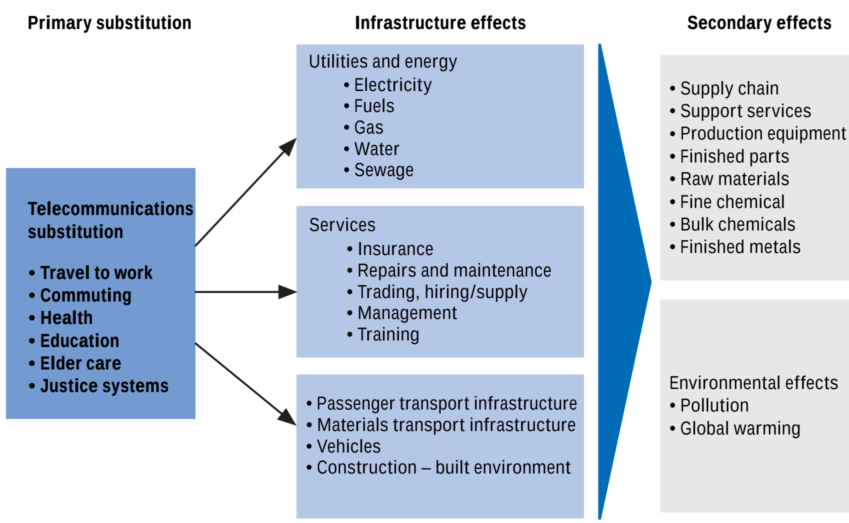
- Reduce consumption of vehicle hydrocarbon fuels and need for their distribution networks, and subsequent pollution from direct and indirect causes.
- Redistribute land usage, reducing urban concentration, attached transport and land use demands.

B) Where telecommunications may augment or extend infrastructure services:

- Reduce health care and elderly care spend yet improve quality.
- Expand educational reach, by distance, age, variety of subjects and materials, for same spend.
- Improve emergency services in efficiency and cost.

Clearly telecoms substitution will not reduce spend on all types of infrastructure. In practice, it may reduce expenditure on some types of infrastructure and could extend the reach of, or reduce, spend on infrastructure services. But for some elements it might expand the demand for infrastructure, for instance, through increased productivity and stimulation of additional activities. The figure below summarises the substitution and secondary effects on other infrastructure elements.

Figure 2.24. **Main branches or relevance tree**



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Electronic mobility impacts on distributions of habitat and workplace

Offshoring – telecommunications facilitates substitution of labour at lower cost

The location of work is determined largely by the availability of a pool of workers with the necessary skills. Similarly, workers need to live in areas close enough to where they work. These two factors define today's location of residence and of employment in services and manufacturing industry, with commuters travelling from suburbs to urban centre or from suburb to suburb. However, telecommunications allows companies greater freedom to locate tasks in different countries, such that they can take advantage of skilled workers either in areas of the country with untapped pools of labour or abroad. Offshoring, or the international sourcing of IT and ICT-enabled business support services, is a recent development in the globalisation of services sectors. Offshoring, enabled by telecommunications, is a response to the need to cut costs or fill skills shortages, against a background of global competition.

When one firm moves to lower-cost locations, competitors are forced to follow. Developments in ICTs increasingly facilitate global sourcing, particularly "knowledge work". This includes data entry and information processing services, research and consultancy services carried out via the Internet and e-mail, as well as tele- and videoconferencing. In the past few years activities such as call centres have increasingly been offshored. In a sense this is not substitution but rather displacement – thus in exporting jobs, effectively infrastructure needs are exported as well – offices, housing, roads, etc.

Data on offshoring are not officially collected but the table below illustrates the scale of the effect on the US economy.

Table 2.16. **US estimated and projected job losses in all sectors due to offshoring**

Estimated jobs lost to date	Projected job losses	Estimated jobs potentially affected
300 000-995 000	3.3 million-6 million	14.1 million
300 000-500 000 (*Goldman Sachs*)	3.3 million over 15 years (*Forrester Research*)	14.1 million (*UC Berkeley*)
400 000-500 000 (*Business Week*)	6 million over 10 years (*Goldman Sachs*)	
995 000 (*economy.com*)		

Note: The total size of the US labour force is 140 million jobs.
Source: OECD, "Potential offshoring of ICT-intensive occupations", Working Party on the Information Economy, STI/ICCP/IE (2004) 19/FINAL, 2005.

The large variations in numbers illustrate the difficulties in measuring the phenomenon. And to put these numbers into context, it should be remembered that about 15 million US jobs are lost and created each year. Nevertheless, the

OECD estimates from analysis of occupational employment data that perhaps as much as 20% of total employment in the EU15, the US, Canada and Australia could be affected by the international sourcing of services activities.[71] Obviously the trend will only be maintained as long as skills are available at relatively low wage and other costs. As activities move offshore, wages will adjust and the offshoring process will slow down.

This will stimulate the search for new locations for offshoring – for North America, countries in the Caribbean and South America provide opportunities, while for Europe the best prospects are in Eastern Europe but also possibly some African counties.[72] It is likely that we will see the emergence of a more complex Web of interrelationships, whereby countries become both sources and destinations for ICT business services. Canada is an example, buying services from low-cost countries and selling them on to the United States. Thus, as value chains get longer, we are also likely to see the emergence of more intermediaries to support the process, *e.g.* brokers, advisers, training providers, location finders, recruiters and local facilities managers. Some of these tasks will be based in the home country, thereby illustrating the complex picture emerging and the likelihood that offshoring will increasingly be offset by the creation of new activities in the home country.

As companies become more experienced with managing offshored activities, the tendency is for more skilled tasks to be offshored, largely because the potential wage savings are highest. For instance, Indian-based radiographers have been used to interpret X-rays for US hospitals, and Mumbai-based lawyers being used by the Thomson Corporation to prepare summaries of US court judgements. It is likely that this trend will continue.

The property usage model and its effects on employment

Populations have increased over the past 200 years with industrial growth, not just in absolute numbers but also in distribution. The move has been from rural settlements and semi-rural market towns and villages for an agricultural economy towards concentration in cities for industrial manufacture. Towards the end of the 19th century suburbia began in earnest in OECD countries such as the United Kingdom and suburban living took off in the 20th century, especially with the rise of the service sector. In the NICs, the first migration is still happening – China has 750 million people in its rural, largely agricultural, economy who are moving to the cities in search of higher paying work.[73]

Advanced telecommunications already means that new models of office usage are emerging in the OECD community and may spread. For instance, the home is increasingly used as office space – the small office/home office market (SOHO) – and traditional offices are changing to centres for meeting and communication, less for work and presence. Thus, demand for office style property might change to welcoming sites with minimal cost, out of town, and to small prestige sites in urban centres, which could be shared. This would tend to reduce both the amount of office space being built, with its infrastructure, and also the travel patterns and energy consumption involved.

Looking to future land usage for housing, with increasing prices, global competition will tend to drive some who can work remotely (knowledge workers) towards previously neglected regions, wherever it is lower cost and in social trends crime is lower, both in open countryside and small towns and villages. The most remote housing could be occupied by those who are full-time teleworkers. Part-time teleworkers, who travel to work once or twice a week only may not mind a longer, irregular commute to cities or regional centres and so will probably prefer lower cost property beyond the limits of expensive suburbia, but within 60 minutes' travelling time to the work centre. A third category is those who will work from a company (or shared) telecottage, in a remote village, chosen for its amenities and costs. Homes may be judged more on their environmental attraction and practical space use, than on urban proximity and public/private transport position. Thus four profiles of residential property are likely to be in demand, all of which should have some homeworking space and be in low-crime areas:

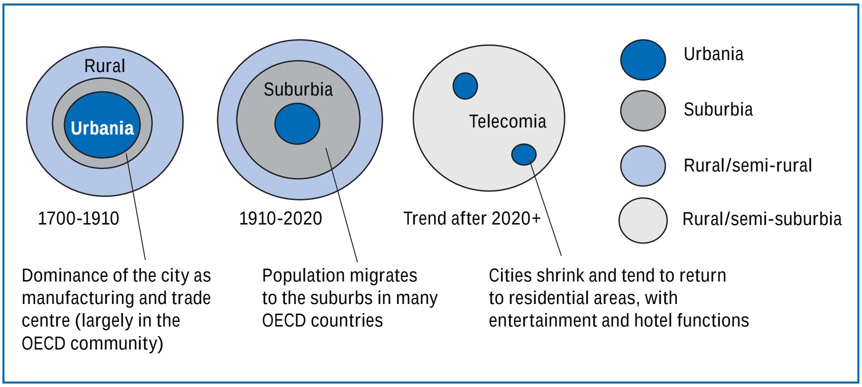
- Low-cost villages and small towns, with good amenities such as schools.
- Remote houses, probably low-cost large properties, for full-time teleworkers.
- Properties beyond the urban sprawl but still commutable.
- Low-cost villages with near-free property for telecottages.

This geographic dispersion in Telecomia or perhaps super-urban sprawl (as characterised by the United States's current "exurbs") is in some ways a return to linked villages of the past, before the industrial revolution, and is depicted in Figure 2.25.

Telecomia would not exist alone, of course. Just as we now have large and small cities and towns, suburbs, semi-rural and rural areas, Telecomia is more likely to develop as an additional feature. In fact it can already be seen in small towns and villages such as Breckenridge in Colorado, Gorde in France or Little Missenden in the United Kingdom. Telecomia will not replace the urban sprawl of Los Angeles, or the poverty of Mumbai, but it might release some pressure.

This new configuration would tend to increase infrastructure spend as support services for habitation such as water, heating/cooling energy and sewage become more dispersed, less concentrated for many people. The local economy would also be stimulated for location-dependent services, local manufacture (*e.g.* fresh bread) and distribution (*e.g.* retail shopping).

Figure 2.25. **Dispersion of residency and workplaces with teleworking and teleshopping**



Nevertheless, these impacts are not likely to be of major significance for two reasons. First, the number of people teleworking is likely to grow only slowly (this is explored in more detail in the section below). Second, it should be remembered that telecommunications and ICT generally traditionally has the effect of supporting urbanisation.[74]

In the developing world the trend towards urbanisation is unlikely to be affected by the availability of teleworking, except where specific policies are put in place to locate knowledge industries in small cities and villages. This would be a way to encourage regional and district employment, as a way of converting a largely agricultural workforce to knowledge work and supporting service industries, while maintaining the national more rural settlement patterns. This would demand either highly developed local education systems, with many tertiary colleges, or the migration of knowledge workers away from urban centres. In the current developing world of China, Brazil and India the current phase is more urbanisation as this is far simpler with the scale of the populations involved being so great. A possible solution might be some form of highly developed distance learning system, but without a large programme to drive it, such an initiative does not seem feasible.

Transport: electronic mobility replaces physical

Effects on road travel

Currently roads in many OECD and developing countries are under pressure. Intra-European traffic was expected to grow by up to 140% over 1990-2015.[75] In the United States 4 billion vehicle hours of delays were predicted for 2005. Roads may already be inadequate in capacity or near to saturation, especially at commuting times with peaks due to passenger-car traffic for travelling to work. With use of telecommunications for telecommuting, traffic could be reduced, and

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so expenditure on new road capacity could be lowered. Effectively, sizing of roads for high *peak* traffic could be avoided to some extent. A further reduction due to telecommunications substitution for road traffic might come from take-up of widespread teleshopping. In total, the same levels of general mobility and service could be offered, but with lower road construction budgets, aimed more at maintenance and improvement of existing roads rather than expansion, assuming congestion reduces.

This would also impact two associated costs to society in infrastructure services – the costs of road accidents and related economic losses, including loss of work output, and also of pollution in terms of health service costs for treatment for bronchial disorders, etc. The impacts of road accident costs on overall health costs, and on the total percentage of beds and care taken up by road accidents, might also shrink in a telecommuting model.

However, telecommuting is spreading only slowly in OECD countries in knowledge worker based economic sectors and it is likely that this slow growth will to continue. According to the International Telework Association, the number of employed Americans who performed any kind of work from home, with a frequency range from as little as 1 day a year to full-time, grew from 41.3 million in 2003 to 44.4 million in 2004, a 7.5% growth rate.[76] Another survey expects 51 million US teleworkers in 2008 with about 14 million people working full-time from home.[77]

Furthermore, the question of whether substitution or complementarity is the more significant factor has been waged in the literature on teleworking for the past 30 years or more. Although there is disagreement:

> The preponderance of evidence suggests that when the scope of inquiry is broad enough, the net impact of ICT is to generate more communication, including new travel. Nevertheless, even if complementarity is accepted as the right answer qualitatively – and some people would contest that – we are not yet able to assess it quantitatively.[78]

Studies show part-time teleworking is more common than full-time, 1.5 days per week on average. Generally teleworkers record longer (substituted) commute journeys than the average national commute journey – in other words, teleworking is undertaken more by people with longer commute journeys. This suggests that the overall potential for reductions of vehicle miles travelled and pollutant emissions may be overstated (*i.e.* that people living closer to work will not telework to the same extent as those living further away, and this should be factored into any estimated aggregate effect). Looking at the range of studies that have been carried out, most typically estimate small reductions in traffic levels, and so it is likely that teleworking would only take the edge off predicted increases in traffic.[79]

As noted, further traffic reduction from telecommunication substitution for travel could come from take-up of teleshopping. However this would increase the number of journeys for *delivery* vehicles from warehouses to the home. Most researchers expect e-commerce to lead to increases in freight traffic, although few quantify their predictions. Some dissenting voices, however, believe that ICT-based increases in efficiency and productivity will mean the same number, or fewer, vehicles on the road. There is no consensus about the impact of e-commerce on passenger trips. Research has explored a number of different scenarios with different business or logistical models, some of which show increases in overall traffic while others show a decrease.[80]

Another possible impact might result from the use of advanced communications technologies to manage traffic congestion. The introduction of congestion charging in London has reduced traffic congestion, taking the pressure off the road infrastructure.

Needs for public transport will continue but so will private mobility

Public transport will still be a major item for public subsidy in 2030 as it is likely to remain a core service in the transport infrastructure in most OECD countries. As described above, teleworking could make a small contribution to relieve the burden on public transport, especially during rush-hour peaks. Long-term telecommunications effects will be more concerned with changing the face of public transport to individualise it and increase its safety, convenience, comfort and user mobility. One example is the use of telecommunications to summon door-to-door bus transport, perhaps mixed with train and taxi, with routes to match the itineraries of passengers.

Infrastructure effects of air travel substitution

Like telecommuting, videoconferencing and audioconferencing have long been promoted as substituting for a proportion of long and short distance business trips. Early forecasts suggested that a significant proportion of business travel could be replaced, but these early predictions have proved to be overly optimistic. Rather than replacing travel, it is now accepted that videoconferencing complements travel patterns. In other words, while some business air travel is replaced, increased efficiency and productivity gains from communications technology translates into extra air travel, thus offsetting some or all replaced business air travel.[81]

A recent study concludes that videoconferencing has only limited effects on business air travel with substitution rates of 2.5 to 3.5%.[82] In a study on teleconferencing suggested that in the longer term, teleconferencing could displace up to 15% of business travel.[83] An FAA-sponsored study by Apogee Research suggests minimum and maximum substitution of 3% and 11% while

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an Arthur D. Little analysis for Boston's Logan International airport proposes diversion ranging between 13% and 23%. Taking all these studies into account, Transport Canada proposes a substitution rate of 6%.

Perhaps use of desktop videoconferencing (with Internet webcams) from home, office or anywhere (with mobile video) could enhance the penetration. The same effect would tend to cap airport infrastructure expansion; under the pressures of oil prices, congestion and possibly pollution, the larger NICs could well use audio and video teleconferencing to substitute for business air travel both now and increasingly up to 2030, with the same proportion – perhaps 10% of business travel – being replaced by some form of conferencing.

Secondary effects resulting from travel substitution

Whatever the extent of the substitution effect, secondary effects would be felt in terms of reductions in:

- The built environment in terms of levels of construction of offices (as workplaces) and shops, as well as roads, with knock-on effects in demands for building, materials, finished parts, bulk and fine chemicals and aggregates, construction machinery, and so on. However, there may be expansion in small and home offices (the SOHO sector).
- The manufacturing sector in terms of vehicles and parts, leading on to reductions in demand for finished goods such as steel and raw materials to make them.
- The services sector which supports the industries of vehicle manufacture and construction of all kinds, from planning to insurance to roadside services.

Hence, direct links to construction, energy consumption and vehicle manufacture characterise substitution for passenger travel with knock-on effects in their supply chain and support services – such as construction machinery hire – and also the tax base, for instance for property taxation. This would lead to a reduction in the supply chain required and its own infrastructure – for instance lower fuels and materials usage would reduce the demand for shipping and ports, reversing the current trends for a global shortage of shipping tonnage.

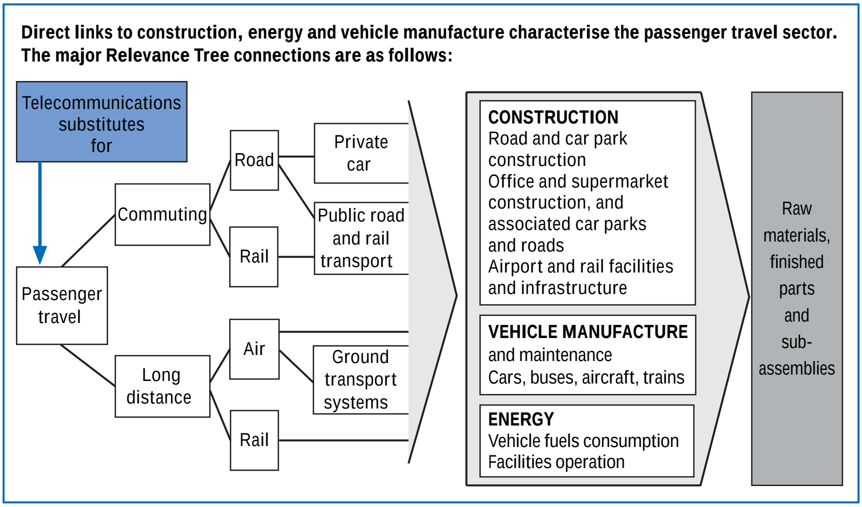
These causal chains of secondary effects are shown in a relevance tree in Figure 2.26.[84]

Energy consumption effects of electronic mobility

Saving on transport costs with telecommuting includes the energy costs in fuels for:

- Private road transport – car journeys for regular commuting and for mundane shopping.
- Aircraft for business trips.

Figure 2.26. **Relevance tree for passenger travel**



However set against this is the potential increased use of fuel for:

- Further road and rail travel for distribution of people, goods, services and infrastructure to more remote sites if urbanisation and suburbanisation is to some extent reversed by teleworking, with residential location in areas more poorly served by transport.
- Increased delivery traffic for teleshopping demands; on balance there should be an overall reduction in fuel as gross miles travelled to shop would be lower.

Thus, the impact is unlikely to be large. Nevertheless, the infrastructure for distribution of various energy sources associated with residence would probably need to be refurbished and/or expanded for a wider distribution of population beyond urban centres:

- *Electricity* – a slightly larger distribution network would be needed in response to teleworking – minor revision will be needed of the distribution infrastructure plus possible resiting or additions to generating capacity for the growing population outside urban centres and suburbia. Diversion into more innovative local generating schemes (wind, solar, wave) may be a far larger factor than previously expected with dispersed populations and pressures to reduce emission of greenhouse gases. Remote telecommunications networks need to be powered, and some novel solutions are becoming available, such as solar powered WiMax and WiFi outdoor transceiver hubs, which also power the backhaul microwave links. The general trends to lower power in mobile radio and alternative wireless technologies will tend to reduce overall power consumption when applied on a large enough scale.[85]

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- There are also plans in some electricity supply companies to re-examine the use of power line signalling for communications, for urban, suburban and rural communities. Thus where there is a power line there could be a broadband connection. Experiments in transmissions to the home or office have been under way for many years, some with backhaul from the local electricity substation via alternative wireless technologies, or via embedded fibre in the high voltage cabling.
- *Gas and other fuels for heating* – an enhanced storage and distribution network for gas would be required in response to the effects of telework, wherever it is economically viable to supply via the piped network. For more dispersed communities, this may never be the case, so that alternative heating energy supplies (heating oil, electricity) would be turned to, increasing their infrastructure demands proportionately.
- *Water, sanitation and sewage* – We would also expect some impact on water and sanitation/sewage infrastructures to require denser network coverage for remote environments.

Telecommunications for infrastructure services

Telecommunications has been promoted over the past decade as a potential advance for infrastructure services – medical care, eldercare for an ageing population, education and justice.

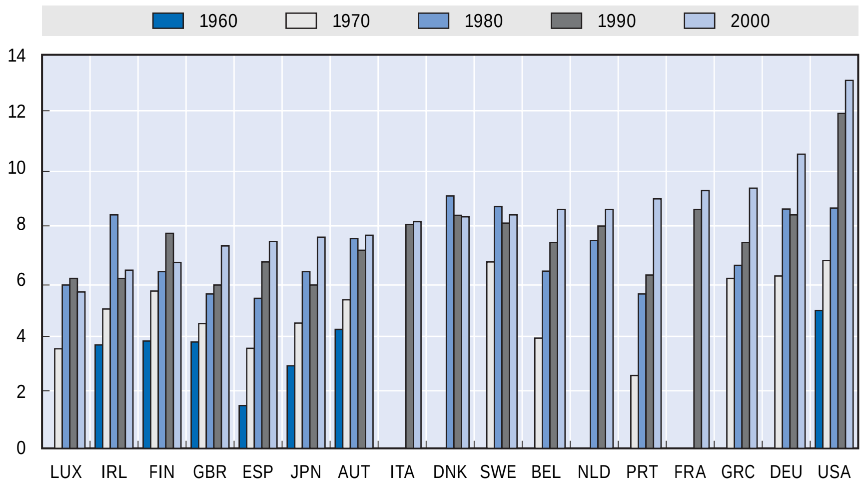
Health systems and telemedicine

Over the past four decades, total expenditure on health as percentage of GDP as been rising significantly towards a median of 8% for OECD countries, as shown below, but with the United States exceeding 12% of GDP.[86]

Today's systems face problems of high inflation in treatment costs, scarcity of trained personnel leading to deteriorating standards of care and challenges from particular medical trends – cardiovascular disorders and an ageing population. Moreover the management bureaucracy surrounding health care is a significant portion of total cost. Telecommunications could provide relief in two principle areas:

- *Telemedicine savings on health care insurance and management* – electronically integrating the various management and payment processes with a new health industry structure. The aim is to closely integrate all players into a new medical record and inter-payments structure, so that savings would come initially on the non-clinical side – in the support systems, medical insurance and payments systems. For the American model, this would amount to perhaps 5% of total costs, near to USD 40 billion for the United States. That country's HMO arrangements and similar systems

Figure 2.27. **Total expenditure on health as percentage of GDP**



Source: OECD, 2003.

could be replaced by an electronic market in health care in which individuals and organisations such as employers, insurance companies or pension funds contract directly for services on a long term or spot basis.

- *Telemedicine savings on clinical treatment* – increased health levels expected on the clinical side from advances in telemedicine use – especially as health care crosses borders and poorer countries may obtain distant consultancy services at low cost. The core question is then to assess the effects in national economic terms of increased health levels. Effects are twofold.
- Savings on national budgets as less needs to be spent to build a viable health system, plus the productivity increases.
- Less lost working days to the economy and insurance restitution costs.

Will telemedicine bring any help in moving to a lower cost model, and if so in what areas of health care? Telemedicine promises advances in seven distinct areas:

- *The sharing of medical expertise across a country and across national boundaries, with improvements in quality and costs.* Accurate assessment of the seriousness of illnesses can be estimated, which non-specialist staff often cannot determine. For instance, a 2-way video link between Atlanta and St. Petersburg in Russia has allowed American doctors to advise Russian surgeons. Equipment was provided by UNM (United Medicine Network), a direct dial videoconference network created for global telemedicine. In

France, a panel of six specialists reviews patients suffering specific skin diseases all over France in one afternoon, so patients get six opinions, not one, using video links and a consensus on treatment can be reached.

- *Promptness of essential care from a specialist whenever necessary for emergency cases,* with the facility for local doctors to obtain an expert opinion not physically present. For instance, when a three-year-old child fell off the refrigerator and opened up a deep wound with no bleeding, a remote nephrology consultant was requested. The specialist carried out an interactive video examination at the local clinic and found transport was safe for the specialist surgery required (source: American Telemedicine Association).
- *Avoidance of travel for treatment for patients, saving lives, cutting costs and preserving beds in remote hospitals*. Also, increased efficiency is possible for medical staff by avoidance of travel; they may work from wherever is convenient and serve more patients in a given time. For situations of health security, telemedicine provides the isolation necessary, for quarantine cases and for remote mental institutions.
- *Remote hospital care in-home, for the sick, aged and infirm, with surveillance and advice* on self-medication, etc., where possible, or advice to local helpers present, with monitoring by alarms and video perhaps combined with the concepts of the "smart house". This development will be essential to cope with an ageing population as expenditure on health care increases with age.

Table 2.17. **Portion of health expenditures for over-65s is increasing**[1]

In per cent

	1980	2040
Sweden	51	65
Belgium	22	30
	1990	2025
Japan	38	58

1. "Health for all in the 21st century?", OECD Futures Studies, Paris, March 1994.

- *Remote teaching or guidance and education, for medical staff, students and patients* or for those under treatment or special care such as expectant mothers, widening the reach of teaching and avoiding travel.
- *Increased efficiency, through electronic document management (EDM)* for the major overheads in patient clinical, and above all health insurance and payments, paperwork (public and private).
- *E-commerce and supply chain management (medical EDI) for ordering supplies* with better inventory control, plus capital savings and lower security risks

for stores of drugs. Moreover, an electronic market worldwide in medicines could also drive down prices, especially as bulk buying with comparison of world prices becomes universal.

- *Creation of a single integrated health care system*, in which patient records, health insurance and payments, and information such as laboratory reports, admissions, beds free, etc. are available to each type of medical operator in the system, on an authorised, secure basis. Telemedicine can bring together the GP, clinic, nursing home for the aged, hospitals and external specialists with outpatients (the patient at home) and the ambulance on the road.
- The maximum savings introduced by telemedicine might appear to be in OECD countries with overburdened health budgets seeking a higher quality of care at lower cost. However the major applications may be in those countries with poor or stretched health infrastructures – the NICs. One study in northwest Russia outlines this case.[87] It found using remote consultations that the expenditure on in-patient treatment can be reduced by half by means of shortening the treatment terms and using small local hospitals with telemedicine links to centres of expertise. This result depends on sharing far more skilled regional centre staff, who have the expertise that is lacking in staff in the district and local health care centres across northwest Russia.

Care of the elderly

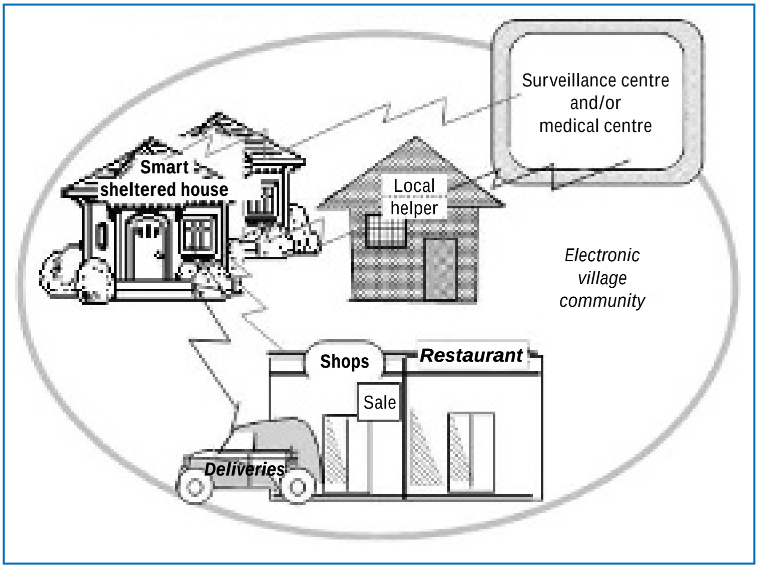
We are ageing. In the developed world, the population of the 60-year and older group has expanded from 99 million in 1950 to 248 million in 2000 and is expected to be 298 million in the year 2050. The 50 and older population from 2000-50 will grow at a rate 68 times faster than the rate of growth for the total population.[88] The US population of 65 and over is projected to rise from 13% of the total population in 2010 to nearly 20% in 2030.[89] By the year 2020, the number of Americans 85 and older will more than double to 6.4 million, and the number of people who are 65 to 84 years will almost double to 47.1 million.[90]

Many elderly and frail people will demand intensive care, and must be looked after in the appropriate category of care environment. But a major proportion of the frail and elderly could be more cheaply and happily supported in their own homes, if help from three innovative sources were present:

- The "smart house" concept – doors, alarms, curtains, central heating, lights, etc., all operated by remote control, with alarms for patient health, intrusion and abnormal events and accidents. The concept is not new and has been refined for elderly people. In the telemedicine scenario it would include passive video surveillance 24 hours per day of the elderly person to a remote centre to ensure all is safe, health monitoring of vital signs and normal activity. This would require open video lines to the smart house – probably alternative wireless technologies, such as WiFi or WiMax with full motion or slow scan.

- Take-out restaurant and teleshopping services – local restaurants provide menus via on-line Web access, boosting local employment for restaurants and for private delivery services contracted to deliver to the door.

Figure 2.28. **Care of frail and elderly at home using telecommunication**



- The paid carer or local helper concept is being pursued in some countries as a way of increasing employment while providing care. In principle, a local helper is paid for part-time work to provide essential help for moving, lifting and cleaning as well as acting on alarms – for instance a window or door has been left open, or a health crisis is taking place and the helper can be first on the scene. This implies tele-monitoring alarms and video surveillance routed to the helper (*via* a cellular mobile/AWT handset) as well as to a central monitoring centre.

Education

Education and lifelong learning are key factors in the development of our future economy – a fact increasingly recognised in both developed and developing countries. In OECD countries, educational attainment continues to grow among the adult population, with a growing number of young people obtaining secondary level qualifications. Progress in higher education is more mixed although the total pool of graduates in OECD countries is growing. Graduation rates vary from less than 20% in Austria, the Czech Republic, Germany and Turkey to more than 40% in Australia, Denmark, Finland, Iceland and Poland.

Thus, to increase participation and graduation rates, education systems must offer more education to more students and pupils with less funds. Yet they must increasingly support ongoing education throughout life in most OECD economies, new types of less formal courses, and higher quality learning environments. As well as most educational institutions being under pressure economically, there is a general change from learning by rote towards creating individual learning environments, suited to the pace of each student for a more thorough and interesting education.

Training – Today training expenditure is limited because too few companies recognise the need to invest in training. The future is constant re-education, probably at least 2 weeks per year or 4% of direct productivity loss, without travelling time, if intensive full-day courses are used. Distance training carried on continually could at least halve the direct productivity loss costs by spreading out training time over the year and avoiding travel.

Tele-education/distance learning – Telecommunications can augment standard educational facilities with distance learning. Access can be instant to all forms of education at much cheaper rates, while the pressure for higher education will increase. As the links between education and individual salary become more evident, so the links between the wage gap between the qualified and the underqualified will become more obvious.[91] There is growing realisation that traditional solutions will not succeed. Recruiting more staff and building more facilities will not provide the answer and is financially untenable. A fundamental re-evaluation of teaching and education is required, especially in higher education, a key result of research and from other sources such as the OECD Futures Database.

Components of future learning environments:

- teaching via interactive video conferencing and narrowcast transmissions;
- Web networking for document access and circulation, and messaging;
- interactive multimedia course materials and documents;
- computer-based learning (of a more advanced kind than that seen in the 1980's);
- document bases with capacity for large numbers of simultaneous network accesses.

All of these together are being considered to address the four major areas of the education "business":

- the education process;
- learning resources;
- learning resource access;
- management of the support framework.

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Two major advances are possible which change the basic process:

- *Interactive videoconferencing* – for distance learning, to share teachers, tutors and lectures and to reach remote students or pupils. This is largely applicable to higher education, although networked programmes over the Internet have been successful in secondary schools. A further development is the use of television, so successfully used in the United Kingdom's Open University courses.
- *Looking and learning via computers* – applicable to both primary and secondary schooling as well as higher education – and becoming far more developed with experiments that go away from right/wrong question styles of instruction to richer learning environments with interactive environments as well as document creation, access and storage functions. For instance, the MUSE project at MIT's Centre for Educational Computing Initiatives (CECI) has developed interactive textbook style multimedia documents for Spanish and French students.

Criminal justice systems

Crime is growing in most OECD countries, driven by rising unemployment and deterioration of social conditions. In a deteriorating crime situation in most OECD countries, justice is becoming more expensive and further stretched. In the United States, direct policing and guarding costs have more than doubled over 25 years to be 1.5% of GDP. To reverse this decline and generally maintain public security, with criminal apprehension, and as well as the processes of justice, imprisonment and rehabilitation may increasingly rely on telecommunications substitution mechanisms to retain security at high levels for the populace at an economic cost with minimal intrusion.

The macro-effect will be an increase in security levels, enabling freer passage of citizens and reducing fear from attack. The growth of no-go areas, for instance by use of video surveillance for policing, in US and French societies will tend to reduce violence and criminal activities. GDP will generally expand in these circumstances, especially for consumer industries requiring physical visits (shops, cinemas, restaurants, etc.). Property damage, insurance and injury losses will generally be lower and so add to GDP.

Criminal justice systems using substitution mechanisms from telecommunications could benefit from remote telecommunications access for arraignment, remote legal visits and court sessions which will bring key justice infrastructure advantages:

- Costs – by use of videoconferencing in a range of justice processes.
- Security, safety and witness trauma – by use of videoconferencing to courts and prisons.

- Efficiency – reduced holding centres and interim confinement facilities.
- Improved justice – easier to track decisions, more open justice and more timely.

Summary – substitution and secondary effects on other infrastructure costs

Although the impacts are not all quantitative – for instance there are qualitative aspects such as the topology of distribution of knowledge workers away from urban centres and from suburban concentration – we attempt to summarise the impacts of that dispersion, and of transport on other infrastructure sectors:

Table 2.18. **Extremes of changes in infrastructure changes with telecommunications substitutions**

Infrastructure element	Investment increase or decrease	First estimate % change increase (+ve) or decrease (–ve)
Road transport infrastructure	**–**	–5 to –10
Air travel (business) infrastructure	**–**	–5 to –10
Fuel oil – car, air transport	**–**	–5
Health care	**–**	–10
Education	**– or same**	–5 to –10
Justice	**–**	–20
Electricity supply	**+**	+5
Gas supply	**+**	+5
Heating oil	**+**	+5
Water supply	**+**	+5
Sanitation	**+**	+5

7. Recommendations

- Regulatory policy should aim to assure there is fair competition in services and technology and a level playing field, so that the dominant players do not act against the common good in protection of sunk costs in infrastructure. Future investments, *i.e.* for investment in all-IP next generation networks, should be made in the same competitive spirit as that which telecommunications deregulation has followed over the last decade. It does not require the protectionism now being afforded to DSL access networks by the administrations in the United States and Japan, and being attempted in Germany, with refusal of unbundling and shared access to competitors. This technology is just the next development stage in networking. Moreover the premise should also be refused that the incumbents can then tax third party Internet portals, search engines and content providers, on the grounds that better service to their end-customers justifies extra charges to such service providers, as Bell South and Verizon propose for the fibre optic local loop.[92]

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- If this is not pursued, the OECD economy will fall behind as other national and regional economies progress with better communications at lower cost. In such economies, telecommunications usages pass on savings in overall infrastructure costs (through substitution) as well as economic stimuli in telecommunications-based education, ecommerce, health, elderly care, etc.
- Competition will also largely take care of the "Digital Divide" – the difference between the privileged and poor in society, which extends down to access to digital services. Certainly supportive action by government may be necessary, but reiterating the liberalisation point above, it should ensure freedom of entry of new services at low cost. For instance in the United States, France and the United Kingdom, local authorities are taking advantage of the low costs of AWT broadband networks to bring free or low-cost Internet access to their municipalities, often against the wishes of the incumbent operator (although some municipalities are being stopped by certain state governments in the United States). The freedom to do this is the key factor. It enables municipal and regional administrations to stimulate the local economy.
- Governments should resist the policy of exploiting short-term financial gains with the radio spectrum and its licences – funds from high licence fees for radio services only act as a structural impediment on competition and new services, and act as a barrier to entry of radio new technologies. Highly priced licences are bought by those with deep pockets – the incumbents – whose aim is to prolong current revenue streams and cut off new entrants who could jeopardise their position, perhaps breaking up a cosy oligopoly. Incumbents have little interest in investing in a competing technology when today's profits and market positions are strong. Secondary markets for spectrum may also be also important in inciting broadcasters to quickly move to digital terrestrial television and give up unused spectrum, and so this should also be a concern for regulatory agencies.
- Mobile is the key technology and new alternative wireless entrants to the mobile market need to be encouraged to ensure competition against entrenched incumbents. Consequently, endorse an open commons for spectrum for new AWTs, with large unlicensed bands and many of them. This will allow new entrants, services and technologies to enter the market unhindered.
- Do not try to regulate VoIP in the same way as other voice telephony – it is not being brought to market by those who have vested interests in the *status quo*. It should follow the path of regulation that has enabled the Internet to flower.
- More research is needed into new radio technologies, including propagation, spectrum sharing and the digital signal processing behind their implementation. It would be well for governments to consider

investments in this field, perhaps at a regional level (*e.g.* the level of Europe) in terms of a radio networking research institute(s).

- Effort should be put into exploring the usage of AWTs for emergency situations, especially for natural disasters with deployment of "instant" networks. The technology will feed back into the commercial sector. This might be a subject for the above research centre.
- In general, it may be wise to review investments in wired broadband, in view of the wireless services that are coming. Encouraging wired DSL may be at the expense of all other technologies.
- The potential impacts of telecommunications substitution mechanisms should be examined and understood in relation to future infrastructure planning, with further investigation and feasibility studies.

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15. For instance, downloading a a full length audio track for a song (2-3 Megabytes in size) for a pre-paid customer at January 2006 rates in the United Kingdom (the most advanced market in Europe in mobile Internet browsing in January 2006) costs between GBP 7.50/Megabyte at Vodafone and GBP 20/Megabyte at T-Mobile. Thus a single 3 Megabyte song would cost over USD 110 to download for T-Mobile pre-paid customer. Maija Plamer, "Download costs price out mobile customers", *Financial Times*, 05 January 2006. This would imply that more competition is needed for such services to take off as pricing is not being contested enough in today's markets.

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ANNEX 2.A1

Technical Annex: Telecommunications Infrastructure History

Fixed line telephony and data – current infrastructure state and its evolution

Developments and modernisation

Over the past 130 years, since the inception of the Bell System in the United States in 1875, the main infrastructure stock in telecommunications has traditionally been in fixed line technologies, originally analogue* voice telephony. This consisted of three major elements, the local loop, the switches and a trunk or long distance network. From the 1970s onwards, most OECD countries transferred to digitised voice with codecs (coder decoders) so that two main signalling systems were in operation in the local loop – the original analogue and also the new digitised voice, using pulse code modulation (PCM) according to CCITT/ITU standards and with dual tone multifrequency (DTMF) dialing.

Digitalisation of the infrastructure 1973-95

Renewal of the technology stock over the period 1973-95, led by OECD countries, moved the infrastructure of most of the world from analogue signalling and control to digital switching and transmission. The benefits of digitalisation included expanded line capacity with advanced multiplexing, a higher complexity of switching, improved speed of call set up end to end, and above all far higher network reliability. A richer set of features could also be added via programmability to customer premises equipment – the handset instrument and the PABXs and key systems. Digitalisation meant the exchange switch effectively became a routing computer and part of a software defined network whose topology could be dynamically adapted to traffic levels

* M.D. Fagen, ed., A *History of the Engineering and Science in the Bell System: the Early Years (1875-1925)*, Bell Telephone Laboratories, New York, 1975.

and abnormal events. This led to lower cost/line, capacity, speed and reliability. Using digital techniques allowed fixed lines to support demand from computer users for data communications via packet switched networks (originally CCITT-X25 with variations such as X32, frame relay and increasingly TCP/IP) although digitised voice remained as a circuit switched service. A new generation of digital network, the Integrated Services Digital Network (ISDN), was launched across OECD countries from 1985 onwards. ISDN line speed standards of 64 kbps and 2 Mbps E-1 lines in Europe set new performance achievements in the local loop (with 56 kbps and 1.5 Mbps T1 lines in the United States) and end-to-end digital technology.

This produced some major functional advances, such as Centrex, and a richer set of customer services. Features were introduced either through the handset instrument or the local switch offering voice messaging, call forwarding, recall last number dialed, short dialling, etc., collectively termed CLASS services (Custom Local Area Signalling Services in the Bellcore nomenclature).

The arrival of fibre optics moved data rates over long distance from hundreds of kilobits per second in the late 1970s towards links at up to a terabit per second from 2000 onwards, an increase of ten million times in capacity. Taking a high quality (16 kbps) duplex voice channel, a one terabit cable can carry over 62 million voice conversations – sufficient for everyone in France to speak with someone in the United Kingdom at the same time. However the pace of infrastructure digitalisation was highly variable even for OECD countries, as shown in the table below for 1990.

Table 2.A1.1. **Degree (%) of digitalisation of the telephone network by 1990 in selected OECD countries**

	Transmission	Local switching	Long distance switching
France	70	70	75
Germany	50	10	22
United Kingdom	100	42	90
Sweden	50	33	50
Greece	30	8	40
Netherlands	95	35	15
Spain	47	5	45

Source: OECD, Telecommunication Network-based Services: Policy Implications, ICCP-18, 1989; CEPT, CEC, OECD.

As shown in Table 2.A1.2, also there were considerable variations among some leading companies as to the extent and pace of digitalisation.

Many countries today have tied together some form of high bandwidth packet switched fibre transmission backbone with circuit switched voice lines.

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Table 2.A1.2. **Digitalisation development[1] (1980-91)[2] – An overview**

Company/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
AT&T[3]	–	–	–	–	80	–	–	–	–	98	100	100
BellSouth[4]	–	–	–	–	4	11	18	28	35	45	51	57
BT[5]	–	–	–	–	–	–	–	2	10	23	38	47
France Telecom[6]	–	11	15	22	35	44	50	55	64	71	78	81
GTE[7]	–	–	–	–	15	30	44	55	63	69	74	80
NYNEX[8]	–	–	–	–	4	9	16	24	38	49	56	60
NTT[9]	–	–	–	–	–	–	–	–	18	28	39	49
Televerket[10]	–	6	8	10	14	18[11]	22	26[11]	29	37	38	47

1. For all carriers except AT&T, digitalisation is defined as number of main lines in use connected with a digital (time-division switched) exchange. For AT&T, digitalisation is defined as traffic switched by a digital exchange.
2. For purposes of divestiture effective 1 January 1984, data for US companies start in 1984.
3. *Source:* Annual Report (1983, p. 10); Telephony (1987, Feb. 2, p. 13), Annual Report (1988, p. 4).
4. *Source:* BellSouth.
5. *Source:* BT Annual Report (1991, p. 37).
6. *Source:* France Telecom Annual Reports (1981-91).
7. *Source:* GTE.
8. *Source:* NTT. Year indicates fiscal year.
9. *Source:* NTT.
10. *Source:* Televerket, Sveriges officiella statistik (1980-86), Televerket, Annual Reports (1987-91).
11. Interpolation.

Source: Bohlin, E., Techno-Economic Management of Investments, Ph.D. Dissertation, Chalmers University of Technology, 1995.

To handle high-speed traffic for data and voice as a bitstream in the hundreds of Mbps and Gbps range, the CCITT ATM (Asynchronous Transfer Mode, or Broadband ISDN) transmission protocol was produced in the 1980s. A whole CCITT synchronous digital hierarchy (SDH) was progressively introduced in the 1990s for high-speed international fibre optic transmission (termed synchronous optical network, SONET, in the US Bellcore convention) to interwork with narrowband ISDN and broadband ATM over fibre. Recently, the need to handle multiple protocols for high-speed transmission with minimal switching delay has led to MPLS (multi-protocol label switching).

In the late 1980s, inter-switch trunk signalling also evolved with CCITT standards to produce SS7 (signalling system 7). This signaling system featured flexible message formatting for high-speed data transmission, designed to support ISDN and the transfer rates of SDH. SS7 also defined a separate network for transporting signalling messages, for far more than one trunk circuit. In the early phases of digital telephony, signalling and voice used the same path but could not use it at the same time. SS7 offers a signaling gateway into other network types, such as the mobile cellular operator's core (or fixed) network. Telecommunications infrastructure includes not just interlinked national public switched networks, be they circuit or packet switched, but also private networks – leased lines for data and voices, sometimes with private switches, for use by companies and public sector organisations. The interconnection of these two infrastructures has been the subject of much regulation. Private virtual networks (PVNs) have also been built on top of the public network.

Future of the fixed network

Under the pressures of mobile infrastructure competition, the arrival of Internet voice (VoIP) and regulation to open up the local loop, the fixed infrastructure – local loop and trunk network – is being divided up as unbundling is taking place while the profitable voice margins disappear. In response, incumbent operators of fixed networks are considering "converged" architectures for "co-opetition" with mobile and VoIP. An example is BT's 21st Century Network (21CN) architecture designed to provide both mobile connection and fixed line to and within the home ("bluephone") and office with a trunk network designed to be the interconnect and backhaul transport mobile traffic for other carriers on a wholesale basis. Fixed-to-mobile "convergence" is changing the fixed infrastructure architecture for all large fixed line operators.

Fixed wireless access by radio – narrowband and broadband – has been around for decades, although dormant, and its history dates back through a series of experiments to 1911, especially for rural telephony. The future seems to promise more of this technology, as Korea and others experiment with broadband access; this is examined below under broadband access. Although there have been successes in rural telephony, fixed wireless has to some extent been a failure so far in OECD countries, with operators such as Ionica and Tele2 who have launched such networks failing to deliver the quality of service required, or pricing to take the market from fixed line. With Broadband a new chapter opens.

Mobile telephony and data, including alternative wireless technologies

The first generation of mobile telephony grew up with the analogue signalling. This became quite sophisticated in the late 1970s with the cellular systems such as the Nordic Mobile Telephony (NMT) and North American TACS standards. Radio communications evolved from pre-Second World War emergency and taxi 2-way radio systems with the addition of the cellular model to geographically repeat frequencies in non-adjacent "cells", as first suggested by Motorola patents in the early 1970's.

There are now a growing range of technologies for mobile, with two major technologies in two generations (G) of digital cellular mobile in place worldwide:

- 2G GSM including 2.5 G GPRS for faster data downloads, originally and principally in Europe but also in use in most regions today, even the

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United States, largely for voice and short messaging services (SMS). The latter is increasingly important in economies such as the Philippines where some customers only use SMS, for cost reasons.

- 3G W-CDMA using the 3GPP standards, rolled out in some parts of Europe and Hong Kong for multimedia higher-speed data and voice, up to 2 Mbps, but largely circuit switched.
- CDMA-1 with extensions for high-speed data such as EVDO, in the United States, China, parts of Latin America , South Korea, etc., and low cost CDMA-450 also used in Russia and elsewhere.
- CDMA-2 for faster 3G operations, for multimedia, emerging in the United States and South Korea.

These are augmented by other forms of mobile radio communications:

- PHS, PCN and other standards in use in Japan, used with the 2.5 G i-mode Internet access service from DoCoMo.
- Tetra, in Europe for PAMR systems.
- Direct broadcast standards for streaming forms of mobile TV to handsets.

However, alternative wireless technologies (AWTs) are increasingly important for the future. Their role is not just voice telephony but rather packet communications that can include voice, and mobile IPv6 protocols will enhance this. In later decades, they could form part of the local loop, and an increasing part of the core network, with gateways into long distance over fibre or satellite or microwave links. Current leading AWTs include:

- WiFi (IEEE 802.11) for wireless LANs for data, but now for VoIP.
- WiMAX (IEEE 802.16) for fixed urban coverage originally but now for mobile.
- Flash OFDM (proprietary from Flarion – may be standardised as IEEE 802.20).
- ZigBee (IEEE 802.15.4) for shorter ranges for sensor networks, including forms of radio frequency identification (RFID).

Broadband mobile communications, especially wireless broadband

The rollout of broadband, in the range of 100 kbps up to 2 Mbps, has accelerated over the past five years. Originally oversold in a technology "push", demand has at last arrived through customer need for faster Internet access.

Access may be asymmetric (*i.e.* large pipe download, thin pipe upload). Broadband access is currently available in the local loop over multiple bearer types:

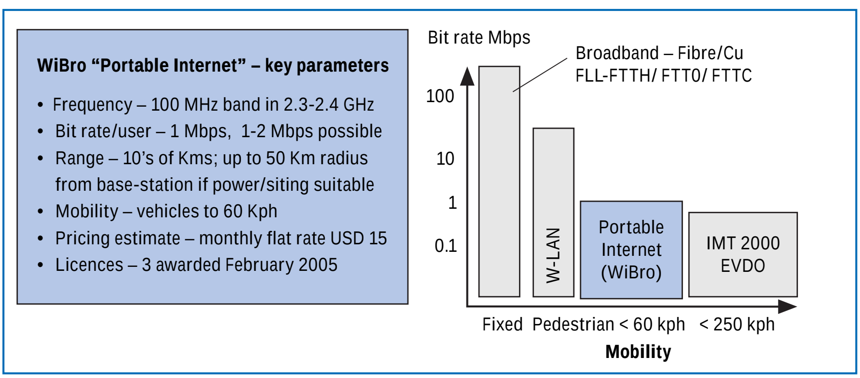
- Enhanced twisted pair – usually some form of DSL (digital subscriber line) typically running at hundreds of kbps. Access modules (DSLAMs) are located in the switch and customer premises, dependent on the propagation characteristics of the copper local loop.

- Fibre to the home or curb, typically via cable TV.
- Fixed wireless access.

In addition, access via satellite is theoretically feasible – failed low earth orbit (LEO) systems such as Teledesic were to offer global broadband access at 1-2 Mbps in the late 1990s, but no commercially viable business plan evolved. Traditional wired broadband infrastructure is being driven by alternative wireless technologies, especially WiFi hubs for Internet access at hotspots for nomadic users.

Some of the latest technology for wireless broadband on a large scale is coming from South Korea, where the "WiBro" system at 1Mbps is being rolled out nationally in 2005/6, to supplement and extend fixed line broadband. As shown in the figure below, being an instance of The Portable Internet, WiBro sits conveniently between several technologies, aiming to offer advantages for data over WLAN and 3G mobile (IMT-2000).

Figure 2.A1.1. **WiBro – key facts and positioning**



Source: KT – interviews & ITU UNS, The case of Korea.

While WiFi is limited to pedestrian speeds of mobility and a range of 100-200 meters, WiBro will also offer mobility, at up to 60 km/h, and provide a range of a minimum of 1 km radius around a base-station with up to 50 kms envisioned, although this would require adequate transmitted and received power and a suitably tall tower to site the WiBro base-station. Samsung is now in negotiations with several US carriers to export the WiBro technology there. Sprint Nextel is to test WiBro in an implementation of the IEEE 802.16e, holding laboratory tests, customer field trials and interoperability tests of WiBro equipment in 2006.

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List of Abbreviations

3G	Third Generation Mobile
CDMA	Code Division Multiple Access
CR	Cognitive Radio
DSL	Digital Subscriber Line
Flash OFDM	Flash Orthogonal Frequency Division Multiplexing
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications (originally Groupe Spécial Mobile)
IPv6	Internet Protocol Version 6
ISDN	Integrated Services Digital Network
MIMO	Multiple In Multiple Out
MMS	Multimedia Messaging Services
MNO	Mobile Network Operator
PSTN	Public Switched Telephone Network
RFID	Radio Frequency Identification
SMS	Short Message Service
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wide Band
VoIP	Voice over Internet Protocol
W-CDMA	Wideband Code-Division Multiple-Access
WiBro	Wireless Broadband
WiFi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
xDSL	Refers collectively to all types of digital subscriber lines
XHTML	Extensible HyperText Markup Language

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Chapter 3

Outlook for Global Investment in Electricity Infrastructure

by

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Summary

The adequacy, quality and reliability of grid-based electricity supply are of crucial importance to economic development and growth. Large amounts of investment will be needed in the coming decades to meet the increase in demand for both the quantity and quality of electricity services, as well as to maintain and replace existing infrastructure that will be retired. Just how much investment will be needed and how much will actually be forthcoming will depend on a range of factors, including macroeconomic and population trends, prices, government policies, technology, and availability of capital.

In a Reference Scenario, in which no new government policies are assumed, global electricity demand is projected to grow at an average annual rate of 2.5% through to 2030. The world consumes twice as much electricity in 2030 as it does today. Developing countries account for much of the increase in global demand, their electricity use more than tripling by 2030. OECD electricity consumption grows less rapidly. Even so, in 2030 the 1.3 billion people in the OECD area still consume more electricity than the 6.5 billion people in the developing world. Moreover, some 1.4 billion in the developing regions still lack any access to electricity – a mere 200 million less than today.

Total cumulative electricity investment needs worldwide in the Reference Scenario amount to close to USD 10 trillion in year-2000 dollars over 2003-2030, equal to about USD 350 billion per year. More than half of this investment goes to transmission and distribution, with distribution taking the lion’s share of overall network investment. Developing countries account for more than half of world electricity investment needs. China’s needs will be the largest, exceeding USD 2 trillion. New investment is also substantial in North America and Europe. Attracting all this investment in a timely manner – especially in developing countries – may not be easy.

In an Alternative Policy Scenario, which considers the impact of new government policies to curb demand growth and promote switching to cleaner fuels, world electricity demand and investment needs grow less rapidly in almost every region. World demand grows by 0.5 percentage points more slowly than in the Reference Scenario as a result of end-use energy-efficiency improvements. Total cumulative investment needs over 2003-30, at USD 8.3 trillion, are USD 1.5 trillion – or 16% – lower. Lower supply capacity requirements more than outweigh the higher capital costs in power generation that result from switching to nuclear power, renewables and distributed generation.

Investment needs will be driven by demand growth. But it is not certain that all of the investment needed will be forthcoming whatever the rate of demand growth, such that some part of demand might go unmet. The main uncertainties surrounding the adequacy of electricity investment worldwide relate to the impact of market reforms, environmental constraints and access to capital. In general, the effects of the first two on investment are most uncertain in OECD countries. Policy makers are seeking to address concerns about the adequacy and timeliness of investment in both capacity and systems to ensure system reliability and an adequate quality of service in those countries by establishing a market framework that sends efficient market signals to investors.

Access to capital – a minor issue in the OECD – is perhaps the biggest uncertainty facing non-OECD countries, especially those in developing regions. They are increasingly looking to the private sector to fund at least part of the investment needed to finance electricity projects, mainly because of constraints on public funding. Yet, obtaining sufficient private sector capital in many cases will be difficult, due to poorly developed local financial markets and an unfavourable regulatory and investment climate. Overcoming these obstacles will require major improvements in governance and continued restructuring and reform in the electricity sector. A particularly pressing challenge is to reform tariff structures both to ensure that prices fully cover costs and to improve revenue collection.

1. Introduction

This chapter assesses the impact of socioeconomic, policy and technological developments on the outlook for global investment in electricity supply infrastructure – power plants and transmission and distribution networks. Modern economies are becoming increasingly dependent on grid-based electricity services. The adequacy, quality and reliability of electricity supply are, therefore, of crucial importance to economic development and growth.

Up to now, the bulk of electricity sector investment has taken place in OECD countries, which continue to dominate the global electricity supply industry. But the picture is changing rapidly, as demand in developing countries surges in response to strong rates of economic and population growth, especially in Asia. Most of the electricity investment over the coming decades is expected to take place in developing countries. But there are indications that financing problems are holding back investment in some countries, undermining prospects for economic development and poverty alleviation. Financing is unlikely to be an issue in OECD countries, but there are concerns about whether utilities are investing enough in capacity, in improving the quality of service to meet increasingly onerous customer needs, and in ensuring the reliability and security of supply.

This chapter first considers past trends in demand for electricity services and in investment in electricity supply infrastructure. It then goes on to review the main drivers of electricity demand and investment needs. This is followed by a summary of the International Energy Agency's latest electricity market Reference Scenario projections, broken down by major world region, and their implications for the amount of investment needed in power generation, transmission and distribution. Results are then presented of an Alternative Policy Scenario, which analyses the impact of a set of new government policies to curb demand growth and reduce energy-related airborne emissions. The following section describes the main uncertainties about whether all the investment needed will actually be forthcoming with respect to both capacity and the quality and reliability of electricity supply. The last section considers the implications of trends in electricity markets, investment needs for the structure of the electricity supply industry, and how new investments could be financed.

2. Past trends in global electricity supply and investment

Market Trends

World electricity supply – gross output from generating plants – totalled 16 742 TWh in 2003. The OECD accounts for most of the electricity produced and consumed worldwide. The United States alone accounts for a quarter of world electricity output and other OECD countries for just over one-third (Table 3.1). However, the share of the OECD area in world consumption has fallen significantly in the last three decades, from almost three-quarters in 1971 to 59% in 2003.

Demand for electricity services has grown rapidly in recent decades. Worldwide, demand expanded at an average rate of 3.6% between 1971 and 2003. OECD countries saw average demand growth of 3.2%, while non-OECD countries experienced growth of 4.8%. Electricity use has grown fastest in developing Asian countries – notably China, where growth averaged 8.4%. The share of electricity in world final energy use almost doubled, from 9% in 1971 to 16% in 2003.

Investment patterns and trends

Comprehensive data on total electricity industry investment are not available, but a number of indicators suggest that global electricity investment has picked up strongly in the last decade or so following a period of stagnation in the late 1970s and 80s. Investment has tended to follow a cyclical pattern around a steadily rising trend, in response to growing end-user demand for electricity. Orders for generating plant, for example, peaked between the late 1960s and early 70s at about 150 GW a year, and then plummeted in the mid-1980s (Figure 3.1). They recently increased again, reaching a new high at the start of the current decade, mainly because of a substantial increase in the

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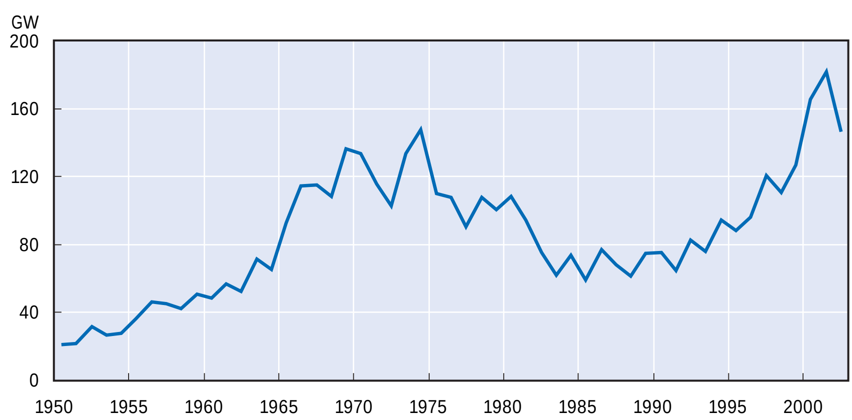
Table 3.1. **World electricity generation**

	1971		2003	
	TWh	Share in world (%)	TWh	Share in world (%)
OECD	**3 831**	**73**	**9 938**	**59**
United States	1 703	32	4 081	24
Japan	386	7	1 047	6
Germany	329	6	599	4
Canada	222	4	587	4
France	156	3	567	3
United Kingdom	257	5	399	2
Other	778	15	2 658	16
Non–OECD	**1 419**	**27**	**6 804**	**41**
China	138	3	1 907	11
Russia	n.a.	n.a.	889	5
India	61	1	633	4
Brazil	52	1	365	2
Indonesia	2	0	113	1
Other	n.a.	n.a	2 897	17
World	**5 250**	**100**	**16 742**	**100**

Source: IEA databases.

Figure 3.1. **Worldwide orders for new power-generation capacity**

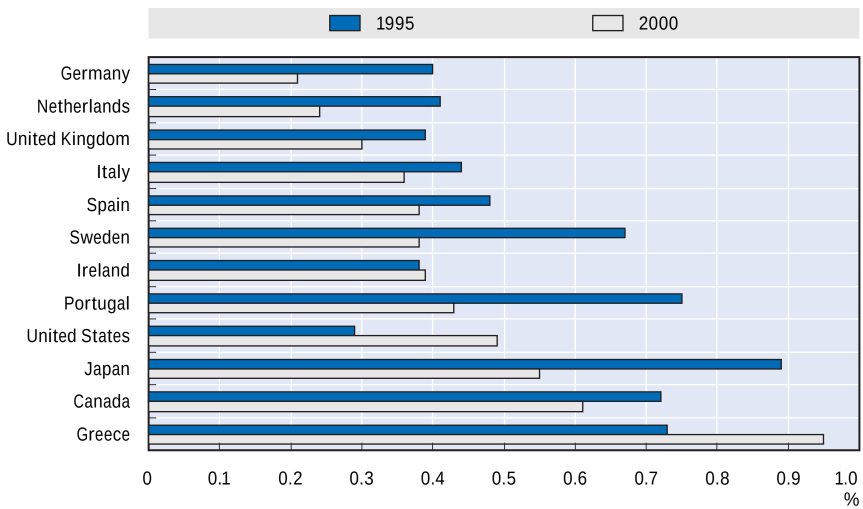


Source: IEA databases.

US market. Investment in transmission and distribution has lagged behind investment in generation in some countries, notably in the United States and some European countries. Nonetheless, global electricity network investment is thought to have risen in recent years.

In OECD countries, power sector investment typically accounts for less than 0.5% of GDP (Figure 3.2). With the notable exception of the United States, investment in the majority of them has declined since the mid-1990s for various reasons, including high reserve margins in some countries, the lower capital costs of new power plants, low demand growth and uncertainty caused by environmental policies and market liberalisation. Competition between utilities has reduced profit margins, especially in markets with excess capacity and low demand growth.

Figure 3.2. **OECD electricity sector investment relative to GDP**



Sources: National and regional electricity associations; IEA databases.

In contrast to Europe and Japan, investment in the United States has increased dramatically over the past few years, peaking at close to USD 57 billion (in nominal terms) in 2001 (Figure 3.3). Most of the increase in investment reflects increased power plant construction.

Investment in the EU electricity industry is currently running at about USD 30 billion per year. It was on average lower in the 1990s than in the 1980s, because the amount of capacity built was lower and because investment was directed towards low capital cost plant, notably combined-cycle gas turbines (CCGTs) (IEA, 2003). Investment in Japan has been declining since the mid-1990s. The level of investment in 2001, at just under USD 20 billion, was about half the 1994 level, as a result of a slowdown in electricity demand.

In most developing regions, power sector investment picked up in the 1990s in response to strong demand growth (Figure 3.4). The biggest increase occurred in China, following reforms initiated in the 1980s. Between 1991 and 2000, China

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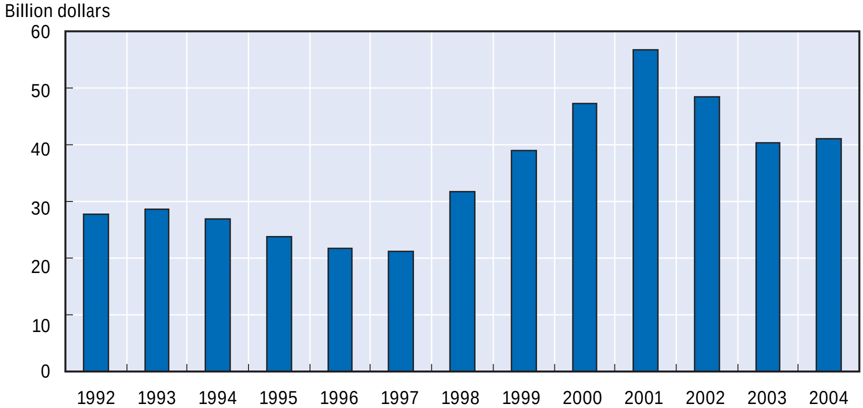
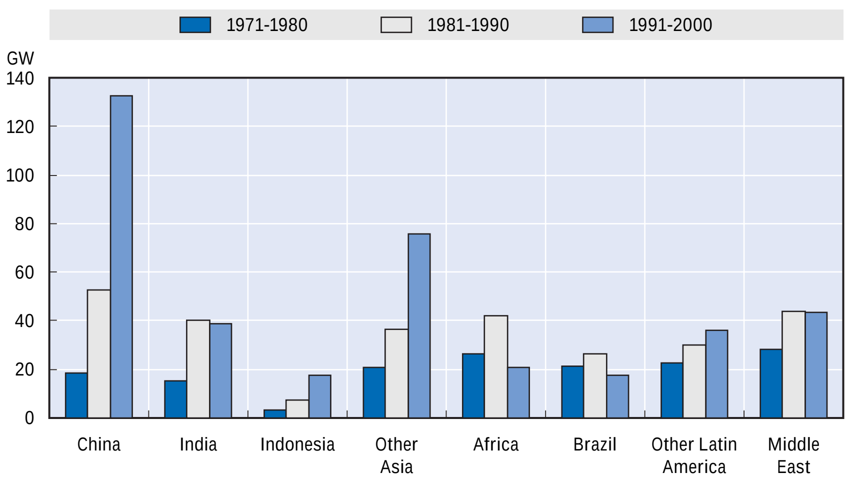
Figure 3.3. **Electricity sector investment in the United States**



Source: Edison Electric Institute (2005).

Figure 3.4. **Annual average capacity additions in developing regions**



Source: IEA databases.

increased installed capacity by as much as all other developing Asian countries put together. Nonetheless, Indonesia and other Asian countries saw continuous expansion throughout the 30-year period, despite the setback in the late 1990s attributable to the economic crisis. The rate of capacity expansion in India, the Middle East and Latin America in the 1980s did not continue into the 1990s. In the Middle East, this can be explained to some extent by the high levels of per capita electricity generation achieved in some countries in the region. In India and Latin America, particularly in Brazil, market reforms aiming at encouraging private investment did not bring the anticipated results. In Africa, the rate of investment in power infrastructure declined in the 1990s, reflecting slow economic growth. Only 5 GW of new capacity were added in the 1990s in sub-Saharan Africa.

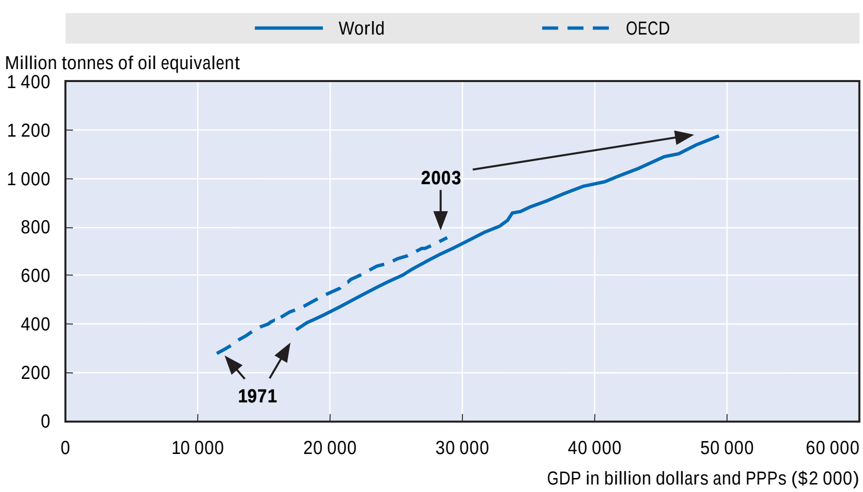
3. Key factors driving electricity infrastructure investment

Electricity supply is highly capital-intensive, with large lead times for building and bringing on stream new capacity. Because electricity is generally supplied in bulk over networks, investment tends to be driven by expectations of demand subject to adequate access to capital. Electricity companies project average and peak load in the near to medium term and attempt to build enough capacity in advance to meet that load. Errors in forecasting capacity needs can lead to sharp fluctuations in investment. The "lumpy" nature of power sector investment also contributes to this phenomenon.

Economic activity is the primary driver of electricity demand, although the relationship is to some extent two-way. Economic growth stimulates demand for electricity services, while the expanded supply of electricity contributes to economic growth and development. Empirical analysis confirms that demand for electricity is closely linked to changes in gross domestic product. Over the past thirty years, the global economy grew by 3.3% per year on average, and electricity demand grew at 3.6%. The relationship is remarkably stable and broadly linear (Figure 3.5).

However, this aggregate picture hides the fact that electricity intensity – the amount of electricity for each unit of GDP produced – has tended to fall in OECD countries, while it has risen in the rest of the world. This largely reflects

Figure 3.5. **World final electricity consumption and gross domestic product**



Source: IEA databases.

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saturation effects in the OECD and catching up by the poorer developing countries. It also reflects changes in the structure of economic activities. Most of the economic growth that has occurred since the 1970s has come from services and light manufacturing industry, which generally require small amounts of electricity per unit of output. In contrast, heavy electricity-intensive industry has contributed more of the increase in GDP in non-OECD countries. The energy efficiency of electric equipment and appliances in those countries is also typically lower than in the OECD, boosting electricity intensity.

Changes in the level and age composition of the population affect the level and composition of electricity demand, directly and through its impact on economic growth and development. A growing workforce will both boost the productive potential of the economy and lead to higher demand for electricity. The ageing of the population tends to increase the number of households and therefore per capita electricity consumption. Migratory movements in population also influence the need for new capacity and investment in production, transmission and local distribution. Migration to regions where capacity is already fully utilised will increase the overall need for investment, unless it relieves the need for new investment in those regions from which the population is migrating.

The price of electricity, in absolute terms and relative to other forms of energy, also has a significant impact on demand and investment needs. The cost of supplying electricity is determined largely by the cost of building and operating power plants and transmission and distribution lines. Maintenance costs are low for most generating technologies and networks. The share of generation in the total cost of supply varies across countries, but is typically more than half. Fuel often accounts for a large part of the cost of generation, and therefore the final cost of electricity to end users. Depending on the choice of technology, increases in oil, gas and coal prices can drive up the cost of electricity and curb demand. Where nuclear power or renewable energy technologies are used to generate power, higher fossil fuel prices can actually boost electricity demand, as electricity becomes cheaper relative to other end-use fuels and consumers switch to electricity.

A host of other factors influence rates of growth in electricity demand and thus the amount and type of investment in infrastructure needed to meet that demand. The most important among these are:

- *Energy and environmental policies.* Government policies affect electricity demand and investment in several different ways. Tax and other economic instruments can deliberately or inadvertently curb demand by increasing the real cost of electricity to end users. Energy efficiency and conservation measures, such as standards, labelling and building codes, can also reduce electricity intensity. Environmental policies may favour some fuels and technologies in power generation, and may hinder the construction of high-tension transmission lines. Regulations requiring power plants to reduce emissions of pollutants such as sulphur dioxide are becoming tighter in many countries, pushing up investment costs. The impact of a range of new policies and measures that might be introduced in the future on electricity demand and investment are analysed in Section 4.

- *Technology.* Advances in power generation, transmission and distribution technology affect both the efficiency and the cost of electricity supply. The deployment of technology that reduces distribution losses, for example, reduces the need for generating and transmission capacity. The choice of generating technology also has a major impact on the amount of capital needed for new capacity: natural gas-fired CCGT plants, for example, often have the lowest investment cost per kW of capacity, although the competitive advantage over other technologies may be reduced by the higher cost of gas compared with coal or other fuel inputs. The choice of generating technology also affects the size and location of power plants and, consequently, the need for transmission capacity. Distributed generation plants located at an end user's site or at a local distribution utility, supplying power directly to the local distribution network, reduce the need to invest in long-distance high-tension transmission lines. Distributed generation technologies include engines, small turbines, fuel cells and photovoltaic systems. They represent a small share of the electricity market today, but the wide range of potential applications and favourable government policies for combined heat and power and for renewable energy technologies are expected to boost their market share over the coming decades (IEA, 2002). Improvements in the efficiency of end-use technology – to the extent that they are actually deployed – also affect electricity demand (see Section 4).
- *Climatic conditions.* Changes in climate, resulting from global warming and leading to marked changes in average ambient temperatures, could have a significant impact on electricity demand for cooling and heating purposes. The impact is likely to be greater for cooling, as the bulk of heating needs in most countries are met by other, more direct forms of energy, such as natural gas and oil products. Air conditioning is one of the leading drivers of electricity demand in many OECD countries and the richest developing economies.

The rate of growth of demand will determine how much investment is needed in supply infrastructure. But there is no certainty that all of the investment needed is forthcoming. If actual investment falls short of that required or is delayed, some part of demand might go unmet, leading to temporary or persistent power shortages. The main uncertainties surrounding the adequacy of electricity investment worldwide relate to the impact of market reforms, environmental constraints and access to capital.

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In general, the effects of market reforms and environmental constraints on investment are most uncertain in OECD countries. Policy makers in those countries are seeking to address concerns about the adequacy and timeliness of investment – both in capacity and in systems, to ensure system reliability and an adequate quality of service – by establishing a market framework that sends efficient market signals to investors. Financing has rarely been a major problem in OECD countries up to now, but doubts about whether investment needs can be fully financed in the future have arisen with the greater investment risks brought by liberalisation of electricity markets. The ability to finance new electricity projects varies among countries, mainly according to the regulatory environment, the extent to which investment has to be funded by publicly owned companies or out of state funds, and where the private sector is responsible for investment – the perceived balance of risk and return. In non-OECD countries, access to capital is the main concern. The private sector is being called upon to finance a growing share of electricity investment as governments find it increasingly difficult to meet rising power-sector investment needs out of their own budgets. Whether all the capital needed can be mobilised quickly enough is a major question.

Uncertainties surrounding the impact of market reforms and environmental policies, as well as the prospects for obtaining sufficient financing from private investors in developing countries, are assessed in Section 5.

4. Outlook for the electricity supply industry

The IEA's *World Energy Outlook* adopts a scenario approach to analyse the possible evolution of energy markets to 2030. The central projections are derived from a Reference Scenario, based on a set of assumptions about government policies, macroeconomic conditions, population growth, energy prices and technology. The Reference Scenario takes into account only those government polices and measures that have already been enacted, though not necessarily implemented. These projections should not be interpreted as a forecast of how energy markets are likely to develop, but rather as a baseline vision of how the global energy system will evolve if governments take no further action to affect its evolution beyond that to which they have already committed themselves.

Other key assumptions in the Reference Scenario include the following:

- Global GDP growth – the primary driver of energy demand – is assumed to average 3.2% per year over the period 2003-30, slightly less than in the previous three decades. The rate is assumed to drop from 3.8% in 2003-10 to 2.7% in the last decade of the projection period, as developing countries' economies mature and population growth slows. The economies of China, India and other Asian countries are expected to continue to grow most rapidly (Table 3.2).

Table 3.2. **GDP growth assumptions in the Reference Scenario**

	1971-2003	2003-10	2010-20	2020-30	2003-30
OECD	**2.9**	**2.7**	**2.2**	**1.8**	**2.2**
OECD Europe	3.1	3.2	2.4	1.9	2.4
OECD North America	2.4	2.4	2.2	1.7	2.1
OECD Pacific	3.5	2.5	1.9	1.7	2.0
Transition economies	0.8[1]	**4.6**	**3.7**	**2.9**	**3.7**
Russia	–1.1[1]	4.4	3.4	2.8	3.5
Developing countries	**4.7**	**5.1**	**4.3**	**3.6**	**4.3**
China	8.4	6.4	4.9	4.0	5.0
East Asia	5.0	4.5	3.9	3.1	3.8
Indonesia	*5.9*	*4.5*	*4.1*	*3.3*	*3.9*
South Asia	4.8	5.5	4.8	4.0	4.7
India	*4.9*	*5.6*	*4.8*	*4.0*	*4.7*
Latin America	2.9	3.4	3.2	2.9	3.2
Brazil	*3.8*	*3.0*	*3.1*	*2.8*	*3.0*
Middle East	3.2	4.3	3.4	3.0	3.5
Africa	2.7	4.1	3.8	3.4	3.8
World	**3.3**	**3.7**	**3.2**	**2.7**	**3.2**

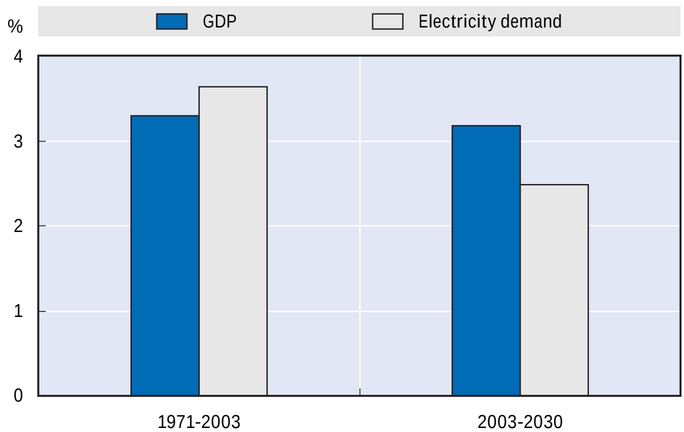
1. 1992-2003.

- The world's population is assumed to expand from 6.5 billion today to over 8 billion in 2030 – an increase of 1% per year on average. Population growth will slow progressively over the projection period, mainly due to falling fertility rates in developing countries. The share of the world population living in developing regions will nonetheless increase from 76% today to 80% in 2030.
- In the Reference Scenario, the average price for IEA crude oil imports is assumed to fall back from recent highs of over USD 60 a barrel to around USD 35 in 2010 in year-2004 dollars, and then climb to USD 39 in 2030 (USD 65 in nominal terms). Gas and coal prices are assumed to move broadly in line with oil prices. Electricity prices in each region are assumed to move in line with marginal power generation costs, which are in turn determined to a large degree by fossil fuel prices.

Electricity demand

In the Reference Scenario, electricity demand is expected to grow at an average annual rate of 2.5% over the projection period (2003-30), as the global economy increases at 3.2% per year (Figure 3.6). The world will consume twice as much electricity in 2030 as it does today. Developing countries will account for much of the increase in global demand for electricity. Their demand will rise at about the same rate as their GDP. Electricity use in those countries is projected to

Figure 3.6. **World GDP and final electricity demand growth in the Reference Scenario**



more than triple by 2030. In the OECD, the pace of growth will be slower, at 1.4% per year. Even so, at the end of the projection period, the 1.3 billion people in the OECD area will still be consuming more electricity than the 6.5 billion people in the developing world. Moreover, some 1.4 billion in the developing regions will still lack any access to electricity – only 200 million fewer than today.

Outside the OECD area, the Asian economies will experience the highest growth in electricity demand. Demand is projected to grow in India by 4.9% per year and in China by 4.5% per year. In 2030, China will generate as much electricity as the United States (Table 3.3). In the transition economies, demand will grow at 2% per year, as these countries are already large consumers of electricity. Moreover, they have the opportunity to use electricity much more efficiently, particularly in industry.

Global electricity use will grow most rapidly in the residential sector, more than doubling between 2003 and 2030. Demand in the services sector will grow by 97%, while industry demand will increase by 86%. Industry will remain the largest final consumer of electricity at the end of the projection period (Figure 3.7).

Power generation and supply

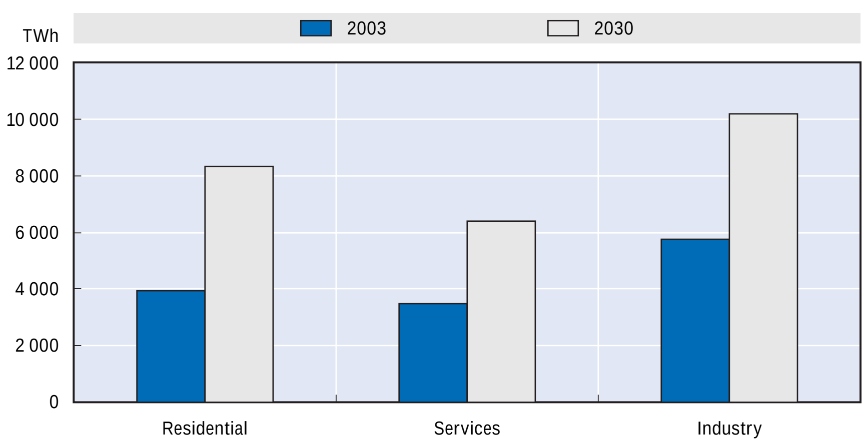
World electricity generation is projected to rise from 16 742 TWh in 2003 to 31 840 TWh in 2030, growing at an average rate of 2.5% per year. The largest increase will be in China, where output will jump by 3 898 TWh in that period, a quarter of the world's projected increase. Coal- and gas-fired generation will provide over three-quarters of the world's incremental demand for electricity between now and 2030 (Figure 3.8). Natural gas and non-hydro renewables – biomass, wind, geothermal, solar, tidal and wave energy – will continue to

Table 3.3. **Final electricity consumption by region in the Reference Scenario (TWh)**

	1971	2003	2010	2030	2003-30[1] (%)
OECD	**3 222**	**8 478**	**9 839**	**12 537**	**1.4**
OECD Europe	1 663	4 152	4 861	6 303	1.5
OECD North America	1 163	2 849	3 187	4 047	1.4
OECD Pacific	407	1 477	1 779	2 198	1.4
Transition economies	**709**	**1 070**	**1 256**	**1 791**	**2.0**
Russia	n.a.	632	721	989	1.7
Developing countries	**442**	**4 117**	**5 699**	**12 142**	**4.2**
China	116	1 477	2 082	4 443	4.5
East Asia	47	605	826	1 733	4.2
Indonesia	2	90	140	361	5.2
South Asia	58	535	709	1 745	4.9
India	52	418	593	1 442	4.9
Latin America	116	663	896	1 768	3.6
Brazil	42	330	384	698	2.9
Middle East	23	442	640	1 151	3.6
Africa	81	395	547	1 303	4.4
World	**4 385**	**13 665**	**16 794**	**26 470**	**2.5**

1. Average annual rate of growth.

Figure 3.7. **World final electricity consumption by sector in the Reference Scenario**



increase their market shares (Table 3.4). The share of non-hydro renewables is projected to rise from 2% in 2003 to 6% in 2030. If countries adopt stronger policies to promote them, a much higher contribution from renewables can be expected by 2030. Coal will lose some of its market share, especially in the OECD, although it will remain the predominant fuel. The decline in coal's

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Figure 3.8. **World electricity generation in the Reference Scenario**

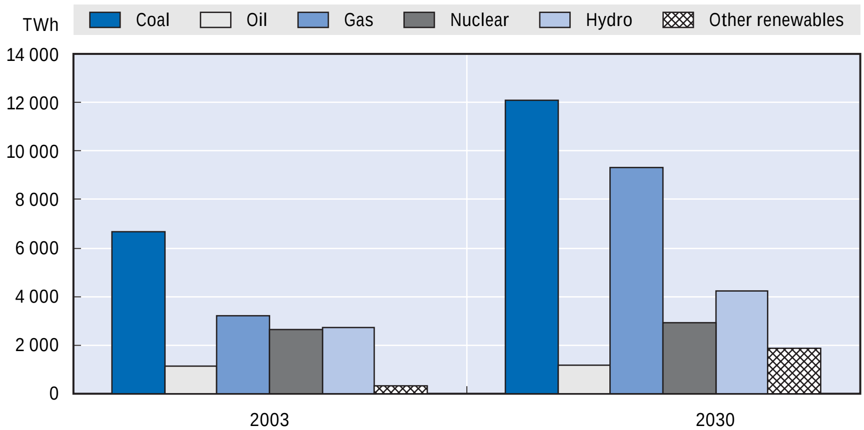


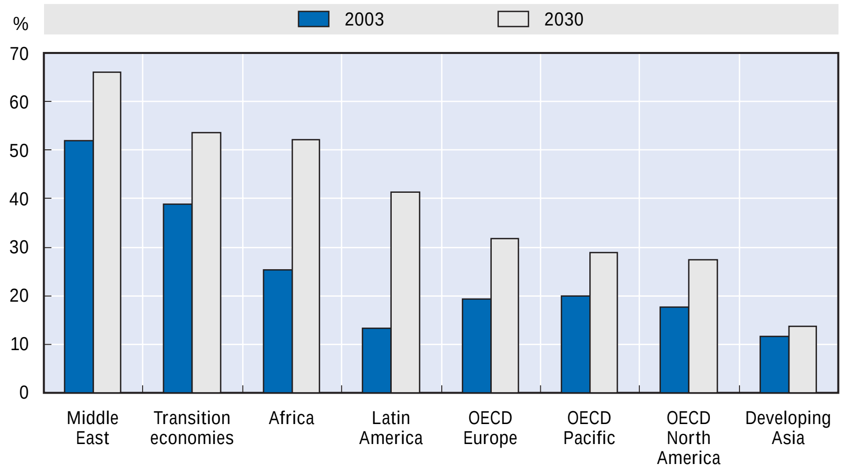
Table 3.4. **Market shares in electricity generation in the Reference Scenario (%)**

	OECD		Transition economies		Developing countries		World	
	2003	2030	2003	2030	2003	2030	2003	2030
Coal	39	33	22	16	47	47	40	38
Oil	6	2	4	2	10	5	7	4
Gas	17	29	39	54	17	26	19	29
Nuclear	22	15	17	11	3	3	16	9
Hydro	13	11	18	15	22	16	16	13
Other renwables	3	10	0	2	1	3	2	6

market share, by two percentage points to 38% by 2030, could be even sharper if efforts to reduce CO_2 emissions are strengthened.[1] The share of oil, already small, will decline still further, falling to 4% in 2030 compared with 7% today. Future oil-fired generation will be concentrated in distributed-generation applications in industry and in remote areas. The share of hydropower will fall from 16% now to 13% in 2030. Nuclear power will lose a large part of its market share, which could drop from 16% now to 9% in 2030 on current policies. Few countries are planning to build nuclear plants.

Gas-based electricity production is expected to triple between now and 2030, continuing a trend that began in the late 1980s and early 1990s. The contribution of gas to generation worldwide will rise from 19% in 2003 to 29% in 2030. Gas-fired electricity generation will increase everywhere in the OECD (Figure 3.9). In developing countries, the share of gas is expected to rise from 17% in 2003 to 26% by 2030. Most of the increase will occur in Latin America, the Middle East and Africa. The transition economies will also see a substantial increase in gas-fired electricity generation.

Figure 3.9. **Share of natural gas in electricity generation by region in the Reference Scenario**



CCGT plants will account for most of the increased use of gas for power. CCGTs are expected to remain the preferred option for new power generation because of their economic and environmental advantages. They have lower capital costs than any other type of base-load plant – half as much as a coal plant, and a quarter as much as a nuclear plant. Construction time for a CCGT plant is two to three years; it takes at least twice as long to build a coal-fired or nuclear plant. CCGT plants have the lowest carbon dioxide emissions of all fossil fuel-based technologies, because of the low carbon content of natural gas and the high efficiency of the plants themselves. This advantage reduces investment risk for gas-fired power plants in countries that plan to limit CO_2 emissions. Natural gas is free of sulphur dioxide, while CCGT technology reduces emissions of nitrogen oxides and particulates. Fuel cells using hydrogen from reformed natural gas are expected to emerge as a new source of power generation after 2020, though their share in total generation will still be very small by 2030.

Electricity supply capacity and investment needs

New power plants with combined capacity of 4 800 GW are expected to be built worldwide over the period 2003-30; half of them will be in developing countries (Table 3.5). OECD countries will need nearly 2 000 GW. China will need more new capacity than any other country or region. More than a third of this new capacity will be built to replace ageing power plants in China: most existing coal-fired capacity will have to be replaced by 2030. Over a third of existing nuclear plants in the OECD are expected to be shut down before 2030, either because they become too old or because of government policies to phase out

Table 3.5. **Electricity generating capacity additions and total electricity investment by region in the Reference Scenario, 2003-30**

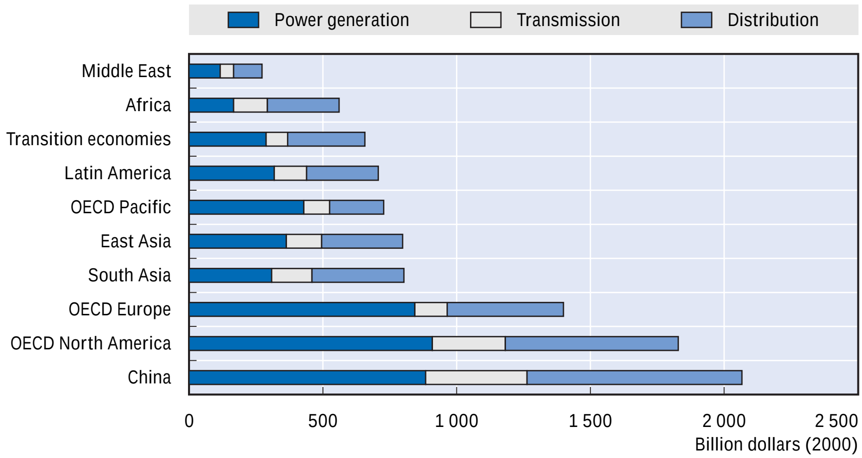
	Capacity additions (GW)	Investment (2 000 USD billion)			
		Generation	Transmission	Distribution	Total
OECD	**1 975**	**2 167**	**498**	**1 276**	**3 940**
OECD Europe	801	842	125	433	1 399
OECD North America	842	910	273	643	1 827
OECD Pacific	332	416	100	199	714
Transition economies	**372**	**287**	**79**	**287**	**653**
Russia	154	138	26	92	256
Developing countries	**2 437**	**2 153**	**962**	**2 090**	**5 205**
China	860	883	378	802	2 063
East Asia	391	364	133	302	798
Indonesia	*77*	*69*	*29*	*67*	*166*
South Asia	349	306	155	340	801
India	*272*	*256*	*132*	*289*	*678*
Latin America	373	317	122	269	708
Brazil	*114*	*125*	*46*	*102*	*273*
Middle East	195	118	48	107	272
Africa	269	165	127	271	563
World	**4 784**	**4 607**	**1 539**	**3 652**	**9 798**

nuclear power. The transition economies will have to build some 370 GW, with half of this capacity replacing ageing nuclear and fossil-based plants.

About 8% of the new capacity that will need to be built worldwide between now and 2030 is already under construction, and another 21% is planned. The largest as-yet-unplanned capacity additions will be in OECD North America and OECD Europe. Africa, Latin America (excluding Brazil) and Indonesia have very little capacity being built. These three regions could fall short of meeting local demand if they fail to attract sufficient investment to speed up construction. China will need to accelerate the pace of construction of new power plants if it is to avoid a repetition of recent electricity shortages. India will also need to accelerate capacity additions to meet increasing demand and to improve electrification rates.

Total cumulative electricity investment needs worldwide will amount to USD 9.8 trillion in year-2 000 dollars over 2003-30, equal to about USD 350 billion per year. Developing countries will account for more than half of world electricity investment (Figure 3.10). China will need the largest increase, exceeding USD 2 trillion. New investment will also be substantial in North America and Europe. Attracting all this investment in a timely manner may not be easy.

Figure 3.10. **Cumulative world electricity investment in the Reference Scenario, 2003-30**



More than half of global electricity investment will go to transmission and distribution, with distribution taking the lion's share of overall network investment. The share of transmission and distribution will generally be highest in non-OECD countries, where there is the greatest need to extend and expand existing networks. In those countries, investment in distribution alone will be almost as large as in generating capacity; in the OECD area, network investment will be little more than half that of power generation investment needs.

Network investment needs are projected to grow steadily through to 2030 (Table 3.6). They grow most rapidly in OECD countries, as demand progressively approaches installed capacity and major new investments are needed. Nonetheless, in the decade 2021-30, network investments in non-OECD countries will be much larger than in the OECD area. Spending in the Big 5 non-OECD countries (Brazil, China, India, Indonesia and Russia) alone will be almost as large as that in the whole of the OECD area.

The bulk of electricity investment will be needed to build new infrastructure. Around 10% of global investment in power generation will go to refurbishment of existing plants. This includes major upgrades, which are assumed to take place once in the lifetime of each plant. Around two-thirds of this investment will occur in OECD countries. The share of refurbishment in total investment will amount to about 13% (16% in North America, 15% in the Pacific region and 9% in Europe). Refurbishment of transmission and distribution infrastructure, including the replacement of cables, substations and control centres, will account for well over half of total network investment worldwide. The share will be highest in OECD countries.

Table 3.6. **Electricity network investment by region and decade in the Reference Scenario, 2003-30**

	2003-10			2011-20			2021-30			2003-30		
	Trans	Dist	Total	Trans	Dist	Total	Trans	Dist	Total	Trans	Dist	Total
OECD	**81**	**205**	**286**	**173**	**446**	**620**	**244**	**624**	**868**	**498**	**1 276**	**1 773**
OECD Europe	20	70	90	45	158	203	59	205	264	125	433	557
OECD North America	43	100	143	94	220	314	137	323	460	273	643	917
OECD Pacific	18	35	53	34	68	102	48	96	143	100	199	299
Transition economies	**10**	**38**	**48**	**30**	**110**	**140**	**39**	**139**	**177**	**79**	**287**	**366**
Russia	3	12	15	9	32	41	13	48	61	25	92	117
Developing countries	**203**	**440**	**643**	**329**	**715**	**1 044**	**430**	**935**	**1 365**	**962**	**2 090**	**3 052**
China	92	196	288	131	277	407	156	329	485	378	802	1 180
East Asia	29	65	93	47	107	154	57	130	188	133	302	434
Indonesia	*5*	*12*	*16*	*10*	*23*	*32*	*14*	*33*	*47*	*29*	*67*	*96*
South Asia	28	62	90	55	122	177	71	157	228	155	340	495
India	*23*	*50*	*73*	*47*	*103*	*151*	*62*	*135*	*197*	*132*	*289*	*421*
Latin America	26	57	83	41	90	131	55	122	177	122	269	391
Brazil	*9*	*21*	*30*	*16*	*36*	*52*	*20*	*45*	*66*	*46*	*102*	*147*
Middle East	7	17	24	17	37	54	24	53	76	48	107	154
Africa	21	44	65	39	83	122	67	144	211	127	271	398
World	**294**	**683**	**977**	**533**	**1 272**	**1 804**	**713**	**1 697**	**2 410**	**1 539**	**3 652**	**5 191**

Alternative Policy Scenario

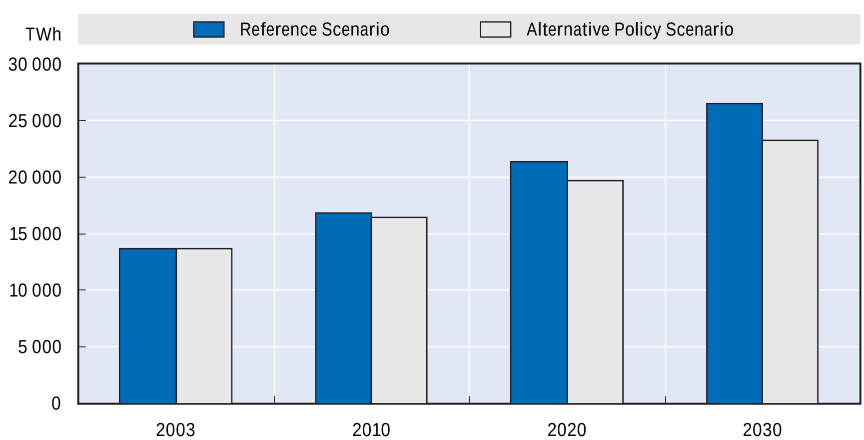
The Alternative Policy Scenario analyses how global energy markets could evolve were countries around the world to adopt a set of policies and measures that they are currently considering or that they might reasonably be expected to implement over the projection period. For each major region, the scenario considers policies to reduce air pollution and greenhouse gas emissions, and to enhance energy security. The choice of measures used to meet policy goals takes into account technical and cost factors, the political context and market barriers. Measures to improve energy efficiency and increase the use of renewables are the main instruments considered. Depending on the region, those measures result from a strengthening or a wider coverage of existing policies, or from the introduction of new policies. The basic assumptions about macroeconomic conditions and the population are the same as for the Reference Scenario. Energy prices change, because of the new equilibrium between supply and demand.

As with OECD countries, the developing country policies assessed in the Alternative Policy Scenario include those currently under discussion at the national level. In general however, there are fewer such policies than in OECD countries because environmental issues and energy security concerns are lower on the agenda than in the OECD area. But it is likely that many of these countries will devise new policies in the future to tackle such problems. In most cases the environmental policies would tackle local or regional pollution, though some countries could take climate change effects into consideration in devising their policies. More efficient and less polluting technologies are assumed to become more widely and rapidly available to these countries, thanks to their faster development and deployment in OECD countries. As a result, global energy intensity falls more rapidly in this scenario than in the Reference Scenario.

Many of the policies considered push for faster deployment of more efficient and less polluting technologies. The rates of efficiency gains vary with local conditions, including past efforts to encourage more efficient energy use and to reduce environmental damage. On average, the improvement in energy efficiency is assumed to be higher in the developing world than in OECD countries. This reflects a far larger potential for efficiency improvements, as well as a faster rate of technology transfer from the OECD area. As more efficient technologies are deployed in OECD countries their unit costs fall, and they eventually become affordable for all countries.

The rate of growth of electricity demand is significantly slower in the Alternative Policy Scenario. In 2030, electricity demand is 3 100 TWh – or 12% – lower than in the Reference Scenario (Figure 3.11). It then reaches 23 202 TWh, an increase of 70% over 2003 compared with 94% in the Reference Scenario. The annual average rate of growth over 2003-30, at 2%, is 0.5 percentage points lower than in the Reference Sceanrio. Energy efficiency measures for industrial processes, appliances and lighting are the main causes of these savings in all regions. The residential sector accounts for 67% of the drop in electricity

Figure 3.11. **World electricity consumption in the Reference and Alternative Policy Scenarios**



demand, with the rest coming from industry (Table 3.7). The overall decline in demand is greatest in the developing countries, where it falls by 13% in 2030 compared with the Reference Scenario. The demand gap between the two scenarios widens progressively over the projection period, as the capital stock in the electricity sector is gradually replaced and new measures are introduced. The difference in electricity consumption is only 2% in 2010.

Table 3.7. **Change in electricity consumption by sector in the Alternative Policy Scenario compared with the Reference Scenario, 2030**

(%)

	OECD	Transition economies	Developing countries	World
Residential	–12.4	–16.7	–15.9	–14.1
Industrial	–9.2	–8.9	–11.5	–10.3
Total	**–10.8**	**–11.0**	**13.0**	**–11.8**

In the Alternative Policy Scenario, world electricity generation in 2030 is 13% lower than in the Reference Scenario. The reduction results mainly from end-use efficiency improvements, which reduce demand, as well as from reduced losses in transmission and distribution and from greater use of distributed generation. The difference between the two scenarios is roughly equal to the current electricity output of the United States. The fuel mix in power generation is also markedly different. In the Reference Scenario, fossil fuels account for 70% of electricity generation in 2030. In the Alternative Policy Scenario, the share of fossil fuels falls to 61%, while the shares of carbon-free fuels rise substantially (Figure 3.12).

In the Reference Scenario, coal's share in electricity generation remains almost unchanged up to 2030, at a little less than 40%. In the Alternative Policy Scenario, coal gradually loses market share, dropping to less than a third of total generation by 2030. At 8 700 TWh, coal-fired generation is 28% lower than in the Reference Scenario (Table 3.8). The decline is sharpest in the OECD, where the share of coal drops to 25% in 2030 compared with 33% in the Reference Scenario. Coal-based electricity generation is 15% less than in 2002, because many coal-fired plants are retired and replaced with plants using other fuels. China and India also see their coal-fired generation reduced by more than a quarter in 2030 compared to the Reference Scenario. Nevertheless, these two countries still account for 45% of the world's coal-fired generation in 2030.

Gas-fired electricity generation, excluding hydrogen, is 1 666 TWh, or 19%, lower in 2030 than in the Reference Scenario, although the share of gas in total generation drops only slightly. Within the OECD area, the largest reductions in gas-fired generation occur in Europe and Japan, where renewables and nuclear energy play a large role. In Russia, gas-fired power plants produce a quarter less

Figure 3.12. **Fuel shares in electricity generation in the Reference and Alternative Policy Scenarios**

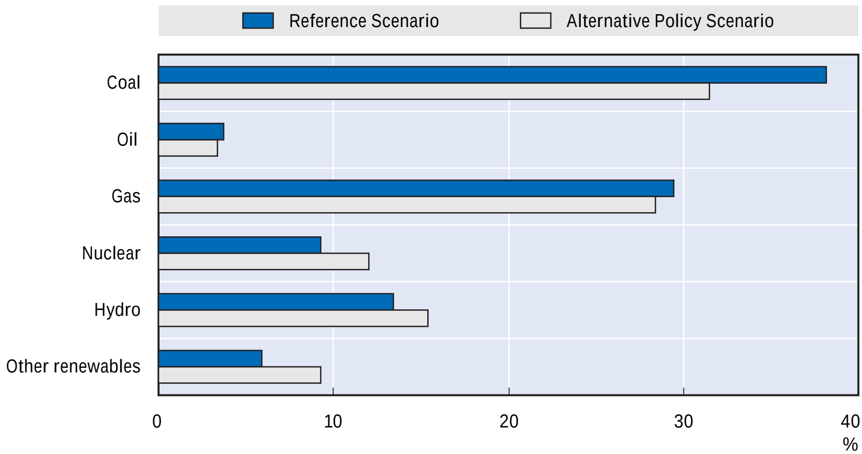


Table 3.8. **Change in electricity generation by fuel in the Alternative Policy Scenario compared with the Reference Scenario**

(TWh)

	2010	2020	2030
Coal	–352	–1 787	–3 392
Oil	–71	–163	–243
Gas	–239	–638	–1 481
Nuclear	15	154	400
Hydro	0	10	19
Other renewables	109	301	692
Total	**–538**	**–2 122**	**–4 004**

electricity in 2030 than in the Reference Scenario. In the Reference Scenario, Russian gas-fired generation nearly doubles between 2002 and 2030 and its share increases from 43% to 53%. In the Alternative Policy Scenario, it increases at a much slower pace and its share increases only slightly, because electricity demand is much lower and because nuclear power substitutes for gas. Global electricity generation from fuel cells using hydrogen from reformed natural gas is 530 TWh, twice as high as in the Reference Scenario in 2030.

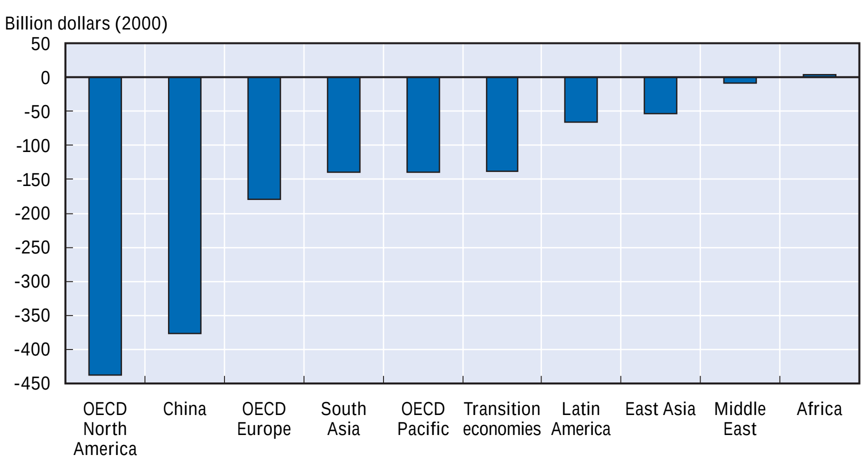
Nuclear power capacity expands to 428 GW in 2030, about 50 GW more than in the Reference Scenario. Nuclear power production is 14% higher. The largest increases in output occur outside the OECD, notably in Russia where nuclear production is 40% higher in 2030 compared with the Reference Scenario. Nuclear production rises by 16% in China and by 21% in India. All three countries have ambitious nuclear programmes and plans for nuclear plant construction.

In the Alternative Policy Scenario, hydroelectric generation in 2030 is slightly higher than in the Reference Scenario. Hydropower's share in world generation drops from 16% in 2002 to 13% in 2030 in the Reference Scenario, while its share falls only by one percentage point, to 15%, in the Alternative Policy Scenario. The share of non-hydro renewables increases much more, from 6% in 2030 in the Reference Scenario to 9% in the Alternative Scenario. The strongest increase is in OECD Europe, driven by the European Union's strong support for renewables. Electricity generation using non-hydro renewables is almost ten times higher in 2030 in the Alternative Policy Scenario than in 2002, and more than a third higher than in the Reference Scenario.

In the Alternative Policy Scenario, worldwide cumulative investment requirements for electricity supply infrastructure over 2002-30 are just over USD 1.5 trillion (in year-2000 dollars) – or almost 16% – less than in the Reference Scenario. Although the average unit capital cost of power generation is 14% higher in the Alternative Policy Scenario than in the Reference Scenario (because of the greater use of more capital-intensive nuclear power, renewables and distributed generation), this effect is more than offset by slower demand growth, which reduces the need for new power plants and new network capacity. The increased use of distributed generation also reduces the need for transmission capacity – and, therefore, investment. The fall in cumulative investment amounts to around USD 300 billion for power generation, USD 375 billion for transmission and USD 860 billion for distribution.

The biggest dollar reductions in investment needs compared with the Reference Scenario occur in North America and China (Figure 3.13). The only

Figure 3.13. **Change in investment requirements in electricity supply by region in the Alternative Scenario compared with the Reference Scenario, 2003-30**



region that sees an increase in investment is Africa, where the higher cost of renewables – which grow much more rapidly than in the Reference Scenario – more than offset the reduction in capacity needs. In percentage terms, the reductions are biggest in North America and South Asia, where electricity demand falls heavily and where the shares of renewables and nuclear power increase less than in most other regions (Table 3.9).

Table 3.9. **Electricity sector investment by region in the Alternative Policy Scenario, 2003-30**

	Cumulative Investment (USD billion in year-2000 dollars)				Difference *vis–à-vis* Reference Scenario (%)
	Generation	Transmission	Distribution	Total	
OECD	**2 088**	**300**	**797**	**3 184**	**–19.2**
OECD Europe	851	81	288	1 220	–12.8
OECD North America	798	175	417	1 390	–23.9
OECD Pacific	438	44	92	574	–19.6
Transition economies	**273**	**52**	**190**	**515**	**–21.2**
Russia	138	17	62	218	–15.0
Developing countries	**1 945**	**813**	**1 807**	**4 564**	**–12.3**
China	775	286	625	1 686	–18.3
East Asia	329	127	290	745	–6.6
Indonesia	61	24	55	140	–15.6
South Asia	261	124	277	661	–17.5
India	219	102	226	547	–19.3
Latin America	298	106	238	642	–9.3
Brazil	121	31	71	223	–18.2
Middle East	110	47	107	264	–3.1
Africa	173	123	271	567	0.6
World	**4 306**	**1 164**	**2 793**	**8 263**	**–15.7**

5. Critical uncertainties surrounding the adequacy of investment

The main uncertainties surrounding the adequacy of electricity investment worldwide in the medium term relate to the impact of market reforms, environmental constraints and access to capital. The relative importance of these uncertainties varies among developed and developing countries. In general, the effects of market reforms and environmental constraints on investment are most uncertain in OECD countries, while access to capital – a minor issue in the OECD – is perhaps the biggest uncertainty facing developing countries.

Impact of market reform

Market liberalisation or reform is creating new challenges and uncertainties in the electricity sector in OECD countries and in many other parts of the world.[2] There is no reason to believe that competitive electricity markets cannot provide incentives for timely and efficient investments (IEA, 2005b). The key requirements are effective competition through properly regulated third-party access to unbundled networks; cost-reflective pricing of network services; and market rules that ensure transparency and low transaction costs. In addition, there is the challenge of creating a smooth regulatory framework for transparent and clear approval processes of new generation plants and network infrastructure. At present, market players are investing in liberalised electricity markets, even without additional capacity measures. Market reforms are expected to bring major economic benefits through more efficient investment and industry operation.

There are nonetheless growing concerns about the adequacy of investment as markets adapt to the new competitive environment. Prior to the liberalisation of electricity markets, electricity companies were usually operated as integrated monopolies, able to pass on their full costs to energy consumers. In such an environment, there was only limited risk in investment decisions. With the introduction of competition in power generation and supply, investors are now more exposed to risk. As competition develops, power companies are being forced to improve their risk management skills and strategies. Physical transmission and distribution activities remain regulated natural monopolies in most cases, though regulated rates of return on capital invested in those areas still need to be high enough to give investors sufficient incentive to expand capacity as demand grows and to maintain existing infrastructure. Investment in power generation, transmission and distribution has fallen in some countries where market reforms have been introduced in recent years, raising fears of a shortfall in peak capacity in the future.

The level of future electricity prices in competitive electricity markets can be a major source of risk to electricity generators and marketers. Price volatility can greatly affect investors' revenues and profits. Uncertain electricity prices expose projects that have a long lead and construction time to additional risks. Economies of scale favour large power projects over small ones, as capital costs per kW for a given technology generally decrease with increasing scale. However, the combination of a long lead time for constructors, uncertain growth in demand for electricity, and the cost of financing add to the risks for these types of investments. Estimates of profitability for such projects rely principally on a long-term market assessment, independent of the spot power market conditions. Very large projects that must effectively be built as a single large plant, such as a large-scale hydroelectric facility, are more vulnerable to this type of risk than projects that can be developed as several smaller power plants, in response to market conditions.

There are a number of ways to manage electricity price risk, for example through the use of long-term bilateral contracts, futures and forwards contracts, either through established or over-the-counter exchanges. The more liquid these markets become, the easier it will be to use these tools. Although fuel prices have always been uncertain, fuel price risks are increased by the liberalisation of the natural gas market. Very long-term contracts are not generally available, with the exception of "take-or-pay" arrangements in LNG markets.

Reserve margins – the difference between maximum available capacity and peak demand – have declined in most countries that reformed their electricity markets in the 1990s. This partly reflects more efficient management and the elimination of excessive spare capacity that had been built previously – a key objective of liberalisation. But this trend has provoked a debate about the appropriate level of reserve margin to ensure that electricity demand will be met during peak demand periods. Supplying electricity at these times requires maintaining adequate generating capacity or buying power from another generator in a market which has a different peak, as well as maintaining adequate transmission capacity. Peak demand is most economically met with power plants of low capital cost, since fixed expenses can be recovered only over relatively short annual periods of operation. The risks to investors building this type of peaking capacity may be high, especially when compared to base-load plant. Such risks include:

- *Market risk*. Peak demand is greatly influenced by weather conditions. Unusual weather patterns such as very warm winters or cool summers could result in certain types of peaking plant not being required at all, and so yielding no annual revenues.
- *Fuel-supply risk*. In systems where the demand for natural gas for space heating and for peak electricity generation coincide, gas supply for space heating will generally be given a higher priority. Thus there is a risk that fuel supply to gas-fired peaking plants could be interrupted or curtailed during cold periods.
- *Regulatory risk*. Because peaking plants are called into service when prices are highest, they are disproportionately exposed to the risk of government-imposed caps on electricity prices.

Market reform is creating uncertainty about future investment in transmission and distribution networks as well. Transmission owners and operators have far less certainty about the demands that will be placed on their networks and, with the unbundling of vertically integrated utilities, less capacity to undertake integrated planning and development of transmission networks as

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a whole. Transmission system operators' capacity to manage system balancing is thus greatly reduced, particularly within regional markets incorporating several owners and operators. At the same time, regulatory and policy uncertainty can heighten the business risks faced by transmission system owners, which can discourage investment. The situation can be further complicated by vested interests seeking to weaken incentives for efficient network performance, and by jurisdictional boundaries cutting across networks and interconnections.

Large-scale blackouts occurred in 2003 and 2004 in a number of OECD countries, notably in North America, Italy, southern Sweden and eastern Denmark. These incidents raised concerns that the transmission infrastructure was inadequate and that major new investment in transmission capacity was needed to improve transmission system reliability. In each of these cases, official investigations concluded that the blackouts were not caused by market reforms. They did, however, raise some issues that will need to be addressed in the future concerning investment in ensuring system security in competitive markets.

Although investment in transmission capacity may help to improve transmission system security to a degree over a period of time, it is not expected to be a critical factor in managing the "operational" reliability of an existing transmission system (IEA, 2005c). This is because system security or reliability is not simply a function of available transmission line capacity. More importantly, there is a need for investment in upgrading and improving system operating tools that would enhance system operators' capacity to effectively monitor, understand and more flexibly control transmission systems in real time. Investment to strengthen the competence and expertise of system operators and other professionals directly involved in the task of maintaining system security helps to improve real-time responses, particularly during emergency situations. Investments that enhance the likelihood of system components operating as designed, especially during emergency situations, may also help to improve transmission system security. The costs of such investments are modest compared with the cost of building transmission capacity.

Investment will increasingly need to be directed at improving the *quality* of supply, rather than simply meeting increased demand for reliable electricity service. This essentially involves ensuring a stable voltage. When the voltage dips below a stable threshold the system can become unstable; this leads to a collapse in voltage, with the potential to cause serious damage to motors and electronic equipment and appliances at the point of use. The growing prevalence of electronics as we move into the digital age is increasing the importance of high-precision electricity supply (EPRI, 2003).

There is enormous potential for developing and deploying technologies to improve operating tools to enhance transmission and distribution system security, and quality of service. This covers the whole range of activities from operational contingency planning through to security monitoring and network control. Better technology can improve the accuracy, quality and timeliness of information. It can also support the development of more accurate and dynamic system modelling, which in turn can allow for more flexible and adaptable contingency preparation and promote greater real-time situational awareness. Technology also has the potential to improve effective operator control over power flows, which would permit more flexible operation of transmission systems and more effective real-time responses to alleviate congestion, manage emergency situations, and enable timely service restoration. Electricity companies and governments are spending considerable amounts of money on developing new transmission technologies in part aimed at improving reliability.

Policy makers are seeking to address concerns about the adequacy of investment by establishing a market framework that sends the right market signals to investors, so that investment is forthcoming when required. The challenge is to exploit the price signals for efficiency that effective markets produce. At the same time, regulators have to take into account cost-effectiveness, reliability concerns and the role of transmission interconnectors in enhancing competitiveness. Some countries have concluded that direct market intervention to stimulate investment in peaking and transmission capacity is unnecessary at this time. In others, measures are being taken to ensure that enough investment in peak capacity occurs so as to guarantee adequate reserve margins. Others are seeking ways to enhance the short-term responsiveness of electricity demand to changes in price, as a means of reducing peak demand and the volatility of prices. Such measures include campaigns to increase consumer awareness of the threat of power cuts when demand peaks, demand-side bidding to induce industrial customers to reduce their load during peak periods, and the use of advanced technology, such as advanced meters, to reduce or reschedule peak load.

Impact of environmental regulations

Environmental regulations, requiring power plants and other industrial facilities to limit or reduce their emissions, are becoming tighter. Uncertainty about future environmental legislation increases investor risk, creating uncertainty about future investment. Existing coal plants in most countries are already subject to controls over emissions of three local or regional pollutants: sulphur dioxide, nitrogen oxides and particulates. However, today's investor faces a high risk of those controls being made tighter and new constraints being imposed on emissions, particularly CO_2. Nuclear power plants may also be subject to additional safety regulations.

More environmental protection will without doubt increase investment requirements for both existing and new power plants. Environmental costs may account for 10% to 40% of total plant costs in fossil-fuelled plants and

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more in nuclear plants. Emissions of sulphur dioxide, nitrogen oxides and particulate matter depend on the fuel mix used in power generation. They are highest in countries where electricity generation is based heavily on coal. Emission standards for these pollutants are tight and becoming tighter in many OECD countries. Developing countries will also be increasingly seeking to reduce these pollutants. This will increase further their already large needs for power sector investment.

Environmental regulation may increasingly address carbon dioxide emissions in all countries. However, in the medium term the impact will be greater in the countries that act to reduce their greenhouse gas emissions under the Kyoto Protocol. Power generation currently accounts for 38% of total energy-related CO_2 emissions in the OECD countries and 40% worldwide. Measures to reduce these emissions will require increased investment in power generation – in more efficient fossil-fuel plants, in nuclear plants, or in renewables-based technologies. Carbon capture and storage may also become a cost-effective option in the medium to long term, though this technology has not yet been proved on a large scale. More investment in upgrading transmission and distribution networks, to reduce losses and therefore the need to generate power, might be a more cost-effective response in some cases. In general, a clear and stable regulatory framework, which gives investors adequate warning of a tightening of environmental regulations, is needed to give investors confidence that current capital outlays will be able to yield a satisfactory return.

Environmental regulations may also make it more difficult to obtain approval to build new generating plant and high-tension transmission lines. The absence of transparent and smooth approval procedures – whether to use a particular technology or to site a new generation plant or network at a particular location – continues to be a serious barrier to investment in many OECD countries. The so-called "not in my back yard" (NIMBY) syndrome was a primary cause of the California power crisis in 2001. The syndrome is expected to become an increasingly serious obstacle to new investment in most parts of the world.

Access to capital

Financing all the investment that will be needed to meet rising demand is a major challenge for the electricity supply industry, and a key source of uncertainty about the prospects for installing electricity infrastructure, especially in developing countries. Their investment needs will increase rapidly in the coming decades. Some developing regions, Africa and India will struggle to mobilise the amounts of capital required.

Investment in electricity infrastructure in developing countries has traditionally been the responsibility of governments. Public utilities in several large developing countries are unprofitable. As a result they are not able to finance new projects themselves. Moreover, investing in new plant is only part of the challenge. Utilities must also purchase fuel to run their power plants. Expenditure on fuel in power stations in developing countries over the next thirty years is expected to be of the same order of magnitude as the investment in infrastructure. The poor financial health of public utilities results from a number of factors:

- *Under-pricing of electricity.* Average electricity tariffs in many developing countries are not high enough for the public utility to cover its full costs. In some cases they do not even cover short-run marginal costs. India is a glaring example of this problem. In 2001/2, the latest year for which data are available, the average price of electricity sold was equal to only about 65% of the full cost of supply (TERI, 2004). As a result, the state electricity boards have been unable to invest fast enough to keep pace with demand, despite additional funding from the central government and private investors for some projects. Shortfalls in peak capacity, which averaged about 13% in 2001/02, result in widespread and frequent power outages and voltage fluctuations.
- *Under-collection of revenues*, caused by non-payment or theft, is also a serious problem in many countries. Non-collection is akin to a 100% subsidy, and can be more distorting and costly than under-pricing of electricity. In some cases, small amounts owed by poor households are not collected for social reasons. But the loss of revenues, by lowering the capacity of the utility to invest, holds back the extension of the network and electrification, especially in rural areas where costs are generally highest.
- *High production costs*, which make it more difficult to eliminate subsidies. The cost of producing electricity in many developing countries is higher than in the OECD area, usually because of low plant efficiency (because of poorly maintained equipment), poor fuel quality, high network losses (because of poor technical performance or theft), high capital costs (because of non-competitive and non-transparent purchases of equipment), high unit transmission and distribution costs (because of low consumption density) and high operating costs (because of poor management and low productivity). Exchange rates also adversely affect a utility's costs when loan servicing and purchases of fuel and equipment have to be made in a foreign currency. Many utilities have accumulated large debts and incur heavy interest charges, which increase their overall costs.

The 1990s saw an increasing number of countries turning to the private sector for part of the investment needed to finance the electricity sector. That trend is set to continue, because of the limited availability of public funds – as the call on government budgets for other forms of spending such as education and welfare increases – and rising electricity investment needs. Governments are also increasingly looking to expand the role of the private sector as a way of improving

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economic efficiency. Yet, obtaining adequate private sector funding will be difficult (see next section). The private sector, while in principle welcoming business opportunities in rapidly growing developing economies, will invest only if it perceives a sufficiently stable and attractive legal framework, and if it can expect returns high enough to compensate for the risks.

While most investment in the developing world is carried out by public utilities or by independent power projects, another source has been direct investment by private electricity consumers in their own electricity-generating capacity, either as back-up to the public supply or as a replacement for it. This response to underinvestment in public supply is most notable in those countries where the quality of electricity supplied by public utilities is poor and deteriorating, such as India, Indonesia and Nigeria. In Indonesia, for example, autonomous electricity producers own 15 GW out of the country's 40 GW of total installed capacity. This trend could become more significant in the future, if shortfalls in investment in centralised production and transmission persist.

Overcoming these obstacles to investment will not be easy. It will require major improvements in governance and continued restructuring and reform in the electricity sector. That will test the institutional capacity of developing countries. Perhaps the most pressing challenge is to reform tariff structures to make prices reflective of costs and to improve revenue collection. It is a major challenge to do this in a way that does not unduly hurt poor households that are not able to afford even basic electric services.

Given the large amount of investment needed in distribution networks in these countries (about USD 2 trillion, or 40% of total power sector investment, over 2003-30), reform of the electricity distribution sector will be of particular importance. In many developing countries, the priority is to reduce non-technical losses from theft of electricity, utility goods and cash, and from non-payment of bills. Such reforms are difficult and take considerable time, at least five years and more likely ten or so. The gap between investment needs and actual investment is likely to continue for some time in the worst-affected countries, with blackouts and brownouts remaining a major problem.

6. Implications for industry structure and financing

Liberalisation and market reforms, largely driven by the goal of achieving more efficient investment in and operation of the electricity supply industry through more private sector participation and the introduction of competition, are having a profound impact on industry structure and the way in which investments are financed. The traditional structure of the electricity utility is a vertically integrated entity, which is often state-owned. Competition is introduced by breaking up or unbundling that structure into its constituent parts – generation, transmission, distribution and supply. In most cases, the physical transmission and distribution functions remain regulated by the authorities as natural monopolies. The way in which the electricity sector has been unbundled varies considerably across countries. The ownership of some components is the same in many cases, but the commercial and operational relationships between them have to be made transparent if competition in generation and supply is to be effective. The participation of a sufficient number of generators and marketers is also a critical condition for effective competition to develop.

Today, the electricity market is organised around power companies whose size varies substantially. The ten largest power companies in the world – led by Electricité de France (EdF) – account for about one-fifth of the world's installed capacity. Until the 1990s most utilities were national, focusing almost exclusively on their domestic markets. In the past decade or so, many utilities chose to invest in other countries and regions. Activity was particularly intense in Europe. A number of large power companies have invested in power projects in developing countries. However, many of these companies are now withdrawing or selling their assets, and interest in new projects in developing countries is very limited.

Several markets, particularly that in the United Kingdom, have recently experienced varying degrees of vertical re-integration. This has involved the horizontal mergers of power-generation and retail companies, and the acquisition by generating companies of retail operations. Economies of scale are clearly a major driver of this reintegration trend, particularly in retailing: a relatively large number of customers seem necessary to make a profitable business of supplying small commercial and residential consumers. In power generation, mergers and acquisitions can help improve the stability of cash flow as a source of finance for large capital-intensive investments in an environment where there is reduced access to debt capital. This has been a key driver in the emergence in Europe of "Seven Brothers" – EdF, E.On, RWE, Vattenfall, Endesa, Electrabel and Enel. These very large electricity firms, which also have significant investments in other businesses, are expected to finance a significant portion of new investment from internal resources. This consolidation has raised concerns about undue concentration and its impact on competition and pricing.

In OECD countries generally, electricity companies finance new projects by providing part of the project capital as equity (internally generated cash or equity issued as public shares). The remainder is financed as debt, with borrowing from banks or through issuing bonds. The current debt-equity structure of OECD power companies varies considerably, with some countries having seen an increase in the share of debt and others a fall (Figure 3.14). Japan relies more on debt, while reliance on equity is larger in the United States. Companies with high levels of debt, such as Japan and France,

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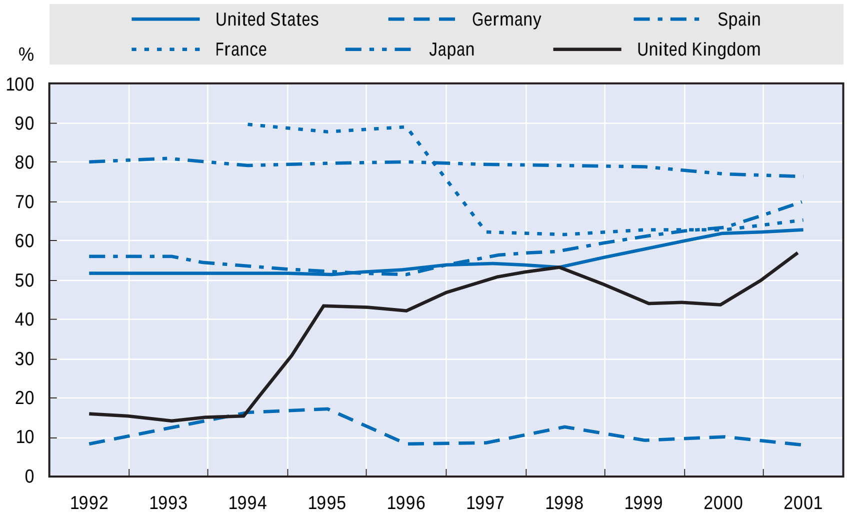
Figure 3.14. **Debt-equity ratio[1] of power in selected OECD countries**

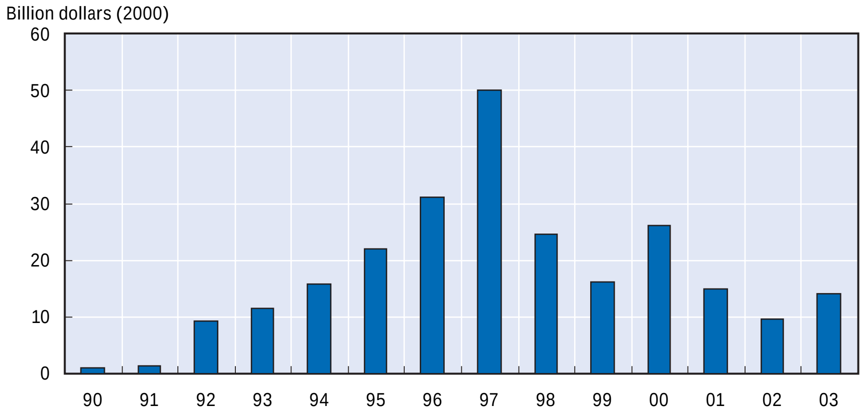


Note: For France, the sharp change in EdF's debt-equity structure in 1997 was due to the issuance of stocks.
1. Share of total debt in the sum of shareholders' equity and total debt.
Source: Standard and Poor's database.

have reduced their debt in anticipation of the emergence of competition. Countries which have seen increased investment in recent years, particularly the United States and the United Kingdom, have increased their debt, although US companies are now looking to reduce debt. It remains to be seen how market reforms and the development of competitive electricity markets will affect the debt-equity structure in the future, and in particular whether the share of equity will move toward the high levels typical in the oil industry.

In non-OECD countries, where utilities are often state-owned and profitability and revenue collection are poor, capital often comes from the government or from multilateral lending agencies, such as the World Bank or the Asian Development Bank. In most developing countries, market reforms have been largely focused on the opening of the electricity sector to private investment, rather than on establishing competitive wholesale and retail markets. Many countries initiated reforms in the 1990s, aimed at attracting private domestic and foreign investment. The initial response was encouraging, but private investment declined rapidly after 1997 (Figure 3.15). Total private sector investment in electricity between 1990 and 2003 in developing countries amounted to USD 249 billion in 2003 dollars. Brazil and other Latin American countries attracted about half of it. However, much of it was spent on existing assets that were privatised rather than on new projects (Izaguirre, 2004).

Figure 3.15. **Investment in electricity infrastructure projects with private participation in developing countries, 1990-2003**



Source: World Bank Private Participation in Infrastructure database.

Reasons for the recent sharp decline in private investment include badly designed investment and energy policies and regulations, economic collapse, and bad business judgements. The result was disappointing rates of return on investment. Many private companies have sold assets they had acquired in the early to mid-1990s. A loss of position in their home markets (notably in the case of US investors) and mergers and takeovers under corporate retrenchment policies (in the case of European investors) contributed to this trend. The result has been a drastic reduction in the number of active international investors in developing countries.

Private investment rebounded in 2003 to just over USD 14 billion, from less than USD 10 billion – its lowest level since 1993. The increase was focused on greenfield power plants in East Asia. There are signs that domestic and regional investors are becoming more prominent in the electricity sectors, especially in Asia. But maintaining the momentum of the growth in financing from this source will take time and appropriate policies. Today, private participation in the electricity sector remains relatively low across developing countries. It is generally highest in power generation and lowest in transmission and distribution, which are usually regarded as a public service (Table 3.10). Participation also tends to be highest in the better-off countries. The role of the private sector is significantly larger in Latin America than in any other part of the developing world. The Middle East and South Asia have been much less successful or interested in attracting private capital.

The ease of financing for electricity projects will continue to vary widely, according to the country in which the investment is made, the risk-return

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Table 3.10. **Share of countries with private participation in the electricity sector by developing region, 2004 (% of sample)**

Country	Power generation	Transmission and distribution
Sub-Saharan Africa	41	28
East Asia and Pacific	67	20
Eastern Europe and Central Asia	41	48
Latin America and Caribbean	68	61
Middle East and North Africa	31	13
South Asia	38	13
Other countries	70	43
Total developing regions	**51**	**37**

Source: Estache and Goicoechea (2004).

profile of individual projects, and whether the investment is in generation, transmission or distribution:

- In *OECD countries*, electricity companies will most likely remain relatively highly leveraged, *i.e.* they will keep their high debt-to-equity ratios. Returns on investment could fall as competition develops, which could drive up borrowing especially for the most leveraged firms and for power generation companies. Transmission and distribution will remain a relatively low-risk business, with returns remaining protected to a large degree by regulators. The cost of their capital will depend partly on how the regulatory framework evolves and, in the case of state-owned firms, the ability and readiness of governments to finance investment themselves.
- In many *non-OECD countries* financing will remain difficult, especially in Africa, the transition economies and South Asia, because of poorly developed domestic financial markets and the higher cost of capital caused by higher risk. Private investment is expected to play a growing role in the medium term, but the success of efforts to attract private capital will depend critically on the economic, political, regulatory and legal environment in each country.

Notes

1. However, the widespread deployment of carbon sequestration and capture technology – not assumed here – could help coal maintain a high share in electricity generation.
2. Many developing and transition economies are seeking to restructure their electricity industries by introducing new market structures to encourage competition. Many of their efforts have not brought about the expected results. Some of these countries may want to delay the introduction of competition until their electricity sector is sufficiently mature and economically viable.

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Chapter 4

Key Factors Driving the Future Demand for Surface Transport Infrastructure and Services

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Executive Summary

This chapter assesses the likely impact of key social, economic, environmental, technological and political factors on future (30-year) demand for road and rail transport infrastructure requirements.

Road transport infrastructure requirements (2000 to 2030)

The key drivers of road transport infrastructure requirements are: *a)* the current existing stock of road infrastructure, as measured by asset value; and *b)* GDP growth, which reflects population growth and per capita income growth. Other factors are considered to have marginal impact around a base-case forecast determined by these economic factors for road transport.

Road transport infrastructure requirements (new construction) of between USD 220-290 billion/year are forecast between 2010 and 30; with perhaps as much as 20% of this amount subject to deliberate policy intervention (*e.g.* fiscal restraint, sustainable development, modal shift to rail) efforts to achieve greater infrastructure efficiency, reduce road congestion and/or improve deteriorating road quality. The largest component of road infrastructure requirement arises from the need to replace/upgrade existing road assets that deteriorate over time. A smaller component actually goes to augment the road capital asset value. Over the entire 2000-30 period, a declining ratio of road capital asset value-to-GDP is forecast – which implies an increase in the productivity of road transport infrastructure.

Rail-track infrastructure requirements (2000 to 2030)

While the same economic factors also determine rail-track infrastructure requirements, government policy to affect modal shift (from road to rail) has an important influence. Rail-track infrastructure requirements (new construction) of between USD 49-58 billion/year are forecast between 2010-30, with a range of ±20% of this amount subject to deliberate policy intervention to fully implement/accelerate rail upgrading to achieve modal shift targets (or not, as the case may be).

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Policy implications

Relevant policy implications arising from these forecasts, which might be usefully addressed in future work in subsequent phases of the OECD Futures Project, include:

- *Infrastructure benefits* are expected to exceed infrastructure costs. Benefits from road transport infrastructure will be more heavily weighted to economic/productivity benefits, while benefits from rail-track infrastructure will more likely be derived from social/environmental outcomes.
- *Economic/business model.* The current model, reliant on annual appropriations control of general tax revenues, will come under intense stress in coping with the heightened fiscal demands of infrastructure requirements. Greater reliance on specific taxes (*e.g.* hypothecated fuel taxes or road fees) and direct road user charges (*e.g.* heavy vehicle charges, tolls) will need to be encouraged.
- *Governance/funding of infrastructure.* In addition to resolving the funding issue for surface transport infrastructure there is the governance issue, which must address asset management, accrual accounting, administration and oversight, and performance reporting issues.
- *Relationships with other infrastructures* will have to be managed from a systems perspective:

  a) *Energy infrastructure*: there is considerable energy demand impact resulting from this forecast of road/rail transport growth, which in turn brings important sustainability/environmental impacts (*e.g.* GHG emissions, fuel efficiency technologies). The author's forecast of road vehicle ownership/use is considerably higher than other forecasts (*e.g.* IEA, WBCSD), which appear to be more optimistic with regard to the possibility of "decoupling" freight (and passenger) transport growth from economic growth – in particular with the impact of growing freight (and passenger) transport intensity from China, Big 5 and developing country growth.

  b) *Telecom (ICT) infrastructure*: technological advances will provide opportunities to improve vehicle safety and network management, with attendant productivity benefits to both road and rail infrastructure. However, these will be marginal relative to the expected growth in vehicle volumes arising from GDP and population growth. The long-term trend is for continued complementarity between *virtual mobility* (information/communications) and *physical mobility* (transport).

  c) *Water infrastructure*: severe climatic disturbances (*e.g.* shifting weather/climate patterns, rising ocean levels) could require additional road and rail infrastructure spending to mitigate risks/damage to both infrastructure sectors.

d) Congested urban areas: integrated infrastructure networks will require careful management in congested urban areas to reduce system-wide life cycle costs and to plan future capacity requirements and right-of-way acquisition to accommodate growth. Subterranean infrastructure asset management and planning will have important cost and security implications.

e) Other transport infrastructures: road/rail connectivity to airports/ports is critical to growing international movements – and there is a danger in many cities that local planning and amenity issues could override national/international interests in improving these connections. Better methods to balance local/regional with national/international interests and concerns are critical.

The "Road Ahead"

There is no doubt that a combined (and concerted) policy involving land use/ spatial distribution/urban density; road-pricing; ICT-inspired improvements in road capacity utilisation; and infrastructure improvements in rail/public modes would have a noticeable and (relatively) significant *marginal* impact on the need for road infrastructure requirements. There is no certainty however that the political constellation(s) will support such a *holistic* policy package – not least as many decisions must be jointly enacted by different levels of governments and require considerable time to build policy consensus.

There are no easy solutions to transport infrastructure funding here. The challenge of funding (and governance) involves a complex mix of public finance, political, economic, environment, and land use issues – with overlapping time frames, decision cycles and deadlines. There is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role for and balance between the two.

Land transport infrastructure (road and rail) has a very long economic life: 30+ years. Capital planning and budgeting require a lengthy (10- to 20-year) cycle that clearly conflicts with 7-year business cycles, 3- to 5-year political cycles and 2- to 3-year budgetary cycles. Any time there is a short-term crisis, long-term plans for land transport infrastructure funding will be sacrificed for short-term expediency to meet other, more pressing political pressures and policy agenda goals.

The public *willingness to pay* for increased land transport mobility will determine whether these land transport infrastructure requirements are met. Road users (direct and "indirect") are a lot like taxpayers in general, so the finance issue should be what is most publicly palatable to fund required transport infrastructure. There will have to be greater willingness to apply user-pay and commercialisation principles for land transport (especially roads) by public finance/transport authorities and their political masters.

1. Key drivers of future surface transport demand

One meta-study of global/regional transport forecasts found that the main factors considered in modelling transport growth are economic growth; population growth; energy prices; and government/environmental policies.[1] Few studies extend this basic forecast set of variables to include income levels; household size; demographic composition; population density; technology (*e.g.* related to energy efficiency); and regulation.[2]

This study develops quantitative forecasts of road and rail infrastructure "new construction" (*i.e.* net additions to capital stock and maintenance construction to preserve the existing value of capital stock) for the period 2005-30. This is based on an economic framework and methodology similar to that implemented by Fay-Yepes (for the World Bank).[3] The data for the key drivers of GDP growth and population growth come from the World Bank and the United Nations respectively, as highlighted in the OECD background paper prepared for this study.[4]

Infrastructure capital stock and new construction model

The Fay-Yepes methodology for forecasting infrastructure capital stock and new construction is based on the economic relationship (*i.e.* elasticity) between infrastructure (road and rail) capital stock and GDP per capita (GDPpc). Growth in GDPpc results in a forecast for road (or rail) capital stock, which can then be transformed into a forecast for new construction (a complete discussion of the model and data sources is in Annex 4.A2).

Generally, the model was developed in detail for road infrastructure, and then adapted for rail infrastructure. The discussion below will focus only on the road model.

A key parameter is the elasticity of paved road capital stock with respect to GDPpc (or GDP). Table 4.1 shows some of the relevant elasticity relationship found in the literature. Under various assumptions, the different capital stock-to-income elasticities can be compared, giving rise to a range of estimates for the elasticity of paved road capital stock with respect to GDPpc of 0.12-0.90, with a mean estimate of 0.20.[5]

Much has been written about how high-income countries have seen a long-term downward trend of transportation investment (and capital stock to GDP) rates:

- EU: the transportation investment rate fell during the 1980s to 0.9% of GDP.[6]
- OECD: public investment rates fell during 1967-90 to about 4% of GDP:[7]
  - transportation investment may be about 1.4% of GDP.
- US: the value of road capital stock fell during 1950-90 to about 13% of GDP.[8]

Table 4.1. **Relevant elasticity relationships**

Study	Variable	Elasticity
1. Capital stock elasticity		
Fay-Yepes	Paved road capital stock	GDPpc 0.23 high income 0.14 low/medium income
Canning	Paved road capital stock	GDPpc 0.90 panel data
Munnell	Public capital stock	GDP per employee 0.30 cross-section
Munnell	Public capital stock	GDP 0.14 time-series
Munnell	Road capital stock	GDP 0.04 time-series
2. Road kilometre elasticity		
Canning	Paved road km	GDPpc 1.20 cross-section
Ingram-Liu	Paved road km	GDPpc 1.00 cross-section
3. Road use		
Hanly *et al*.	Vehicle stock	Income 0.73 cross-section
Johansson-Schipper	Vehicle stock	Income 1.00
Ingram-Liu	Vehicle stock per road (km)	GDPpc 0.30 cross-section
Hanly *et al*.	Vehicle distance driven (vkm)	Income 0.81 cross-section
Johansson-Schipper	Vehicle distance driven (vkm)	Income 1.20
EU	Vehicle distance driven (passenger-km, tonne-km)	GDP 1.00 time-series

The third of these results implies a time-series elasticity of paved road capital stock with respect to GDP of 0.84[9] – which is consistent with an elasticity with respect to GDP per capita of about 0.27.[10]

It is more difficult to evaluate "investment rate" trends, as (on average) more than half of infrastructure spending is on maintenance of the existing capital stock value and the remainder is on new additions to the capital stock. Whether or not "new construction" actually augments the capital stock depends on whether the replacement investment rate is "optimal" (*i.e.* sufficient to maintain the capital stock value). If this is not the case, then some proportion of the "new construction" is required to replace (*i.e.* rebuild) existing road infrastructure that is being "worn out" (*i.e.* fully depreciated in accounting terms; requiring rebuilding in engineering terms). There has been a noted "underinvestment" in transport infrastructure during the 1980-90s in many industrialised countries (due to public spending restraint), so that actual levels of maintenance spending may well be sub-optimal. In the absence of modelling the entire capital depreciation process, and given the relationship of actual maintenance investment to "optimal" investment, it is difficult to reliably relate "new construction" rates (or dollar values) with net additions to the road capital stock.

For example (based on assumptions), the OECD trend would imply a time-series elasticity of paved road capital stock with respect to GDP of 1.95, if 100% of new construction is an augment to road capital stock.[11] In order for the elasticity of paved road capital stock with respect to GDP to be in the order of 0.84 (as above for the US trend), we would have to assume that only 30% of "new construction" is a net addition to the road capital stock. This latter result would indicate that while 50% of road spending might be on new construction, only a third of this (15% of overall road spending) might be a net addition to the capital stock. Another way of stating this is that for every USD 1.00 net addition to road capital stock, it may be necessary to spend USD 6.67 (*i.e.* 1/6) on roads, or about USD 3.33 on "new construction".[12]

The Fay-Yepes approach did estimate components for both net-additions to the capital stock and for maintenance, with only a slightly higher amount of maintenance (60%) relative to net additions (40%). Our analysis suggests that the maintenance component may need to be much greater (by a factor of 2) in the future.

In the Fay-Yepes approach, a two-tiered set of capital stock responses is used:

- For high-income countries (HIC), based on panel data (pooled cross-section and time-series), the elasticity of paved road asset value (*i.e.* infrastructure stock) with respect to GDP per capita is 0.23.
- For low-/medium-income countries (L/MIC) the elasticity is 0.14.[13]

Using these relationships, a world paved road new construction estimate of about USD 260 billion/year was made by Fay-Yepes (see Table 4.2) for the period to 2010 – which involved annual infrastructure growth of about 1.6% for high-income countries, 2.3% for medium-income countries, and 1.4% for low-income countries.[14] The new construction figure was comprised of USD 116 billion of net addition to the capital stock, and road replacement capital investment of about USD 143 billion/year.

As will be seen in Section 2, our comparable (perhaps more involved) methodology is fully consistent in terms of order-of-magnitude with these forecasts.[15] Besides a careful review of and modifications to the underlying methodology, this model has the advantage of extending the analysis beyond 2010 to 2030.

Table 4.2. **(Fay-Yepes) Road infrastructure estimates to 2010**

	Total infrastructure stock 2000	Total infrastructure stock 2010	Growth-infrastructure 2000-10	Annual investment-infrastructure	Annual % growth
Regions of the world					
1. High-income/industrialised	3 951	4 587	636	63.6	1.61
2. Medium-income	1 177	1 450	273	27.3	2.32
3. Low-income/developing	1 001	1 143	142	14.2	1.42
4. Developing (low/medium income)	2 178	2 593	415	41.5	1.91
East Asia and Pacific	681	811	130	13.0	
Europe and Central Asia	371	442	71	7.1	
Latin America and Caribbean	552	657	105	10.5	
Middle East and North Africa	186	221	35	3.5	
South Asia	231	275	44	4.4	
Sub-Sahara Africa	158	188	30	3.0	
World	***6 129***	***7 180***	***1 051***	***259.4***	***1.71***

The result that developing countries will need to invest in roads at an accelerated rate is consistent with empirical evidence that finds general underinvestment in road infrastructure among less-developed regions. Over the period 1950-92 (using panel data), there were strong relationships running bi-directionally between infrastructure (including paved roads) and GDP per capita – implying long-run causality in both directions. The effect was not homogeneous across all countries: the productivity-enhancing benefits of additional infrastructure spending is determined by whether the infrastructure stock is in "wealth-maximising" equilibrium (*i.e.* is optimal). Where infrastructure stocks are below optimal, additional spending on infrastructure is productivity-enhancing, whereas additional spending on infrastructure is destructive of wealth when infrastructure stocks are above optimal (*i.e.* overbuilt).[16] While the net (global) impact of additional infrastructure spending was about zero (*i.e.* infrastructure stock about optimal), there are clear signs of underinvestment in infrastructure in most developing countries, especially for paved roads.[17]

Key drivers for road capital stock and new construction

By far the biggest driver for future road transport use and infrastructure comes from growth in GDP and population – and rising GDP per capita. This is modelled directly in terms of the impact of GDP growth on road capital stock, but it is also observed and used for measures of road use and vehicle ownership.

The elasticity of vehicle stock with respect to income (*e.g.* GDP) is 0.75-1.25, with a mean estimate of 1.0; meanwhile the elasticity of annual per vehicle driving distance with respect to income is 0.05 to 1.60, with a mean estimate

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of 0.2. Taken together, the figures imply an elasticity of distance travelled with respect to income is 0.65-1.25, with a median estimate of 1.2.[18]

World GDP growth of 2.7-3.1% per annum is forecast by the World Bank over 2000-15. Here, the later period growth trend is continued for the entire period to 2030. World population growth of 0.8-1.2% per annum is forecast by the United Nations over 2000-30. The resulting World GDPpc growth rate is 1.8-2.1% per annum. A summary of the key economic growth assumptions are found in Annex 4.A3.

Key drivers for vehicle ownership and road use

Prior to estimating a model for paved road capital stock and new construction, a forecast for vehicle ownership and road use was made (see Annexes 4.A4 and 4.A5 for forecast details). The key variable is road vehicle ownership, which is clearly linked to GDPpc growth on a log-log basis. A key "threshold" of accelerating vehicle ownership occurs around USD 5 000 per capita GDP. This non-linearity is modeled through a simple step function, with a transition occurring between USD 5 000-10 000 GDPpc.

Table 4.3 shows rapid growth in road vehicle ownership per 100 population (vhp) for Big 5[19] countries (principally China) – with a slow upward trend for the world as a whole.

Table 4.3. **Vehicle ownership forecast**

Region	2000 vehicles per 100 pop.	2010 vehicles per 100 pop.	2020 vehicles per 100 pop.	2030 vehicles per 100 pop.
Industrialised				
OECD	52.0	55.8	63.3	72.4
Non-OECD	19.0	24.1	32.6	43.6
Developing				
Big 5	2.9	4.2	8.8	14.6
Others	5.0	5.4	6.7	8.3
World	**13.1**	**14.4**	**18.0**	**22.5**

Rapid motorisation and growth in vehicle ownership in China (and other Big 5) is of great concern for energy and transport planners. Independent forecasts see China vehicle ownership grow from 0.6-1.3 per 100 population (vhp) in 2000 to 3.9-11.9 in 2020. There is comparable growth in India from 0.4 to 1.2, and in Indonesia from 1.5 to 6.7.[20]

Table 4.4 shows rapid growth in annual distance driven, which is the product of total vehicles and an estimate of annual distance per vehicle (adv) – which trends downward over time for most industrialised countries, with

Table 4.4. **Road use forecast**

Region	2000 distance driven (Bvkm)	2010 distance driven (Bvkm)	2020 distance driven (Bvkm)	2030 distance driven (Bvkm)
Industrialised				
OECD	10 323	11 558	13 734	16 484
Non-OECD	917	1 205	1 697	2 285
Developing				
Big 5	2 322	3 808	8 226	13 677
Others	2 517	2 966	3 974	5 186
World	**16 079**	**19 537**	**27 631**	**37 632**

"convergence" around 15 000 km/vehicle/year in the long term as vehicle ownership rates increase.[21] Rising GDPpc and vehicle ownership rates in industrialised countries are expected to increase total annual distance driven by 67% over the 30-year time period, but will result in a 290% increase among Big 5 and developing countries. This puts some stark figures to the challenge for energy sources and global sustainability.

Key drivers for rail capital stock and new construction

While there are economic drivers for future rail use and infrastructure – principally for rail freight growth – the nurturing and encouragement of rail passenger use is primarily determined by government policy and specific investment programmes (*e.g.* TEN-T priority projects). This has very consciously been a "sustainability" policy agenda to shift some road use to rail and at least dampen somewhat the future growth in local passenger road use (*e.g.* commuters) and intercity air use (*e.g.* business, pleasure), although there is a growing awareness that forms of inter-metropolitan interaction are blurring the distinction between daily commuter and intercity travel.

2. Future requirements for surface transport infrastructure

Based on the models developed in the preceding section, future "new construction" infrastructure requirements for both roads and railways have been developed. It should be noted that the road-model is the more robust and carefully analysed model, while the rail-model should be treated as highly indicative.

Road infrastructure requirements

Table 4.5 summarises the key estimates for road new construction for the years 2000, 2010, 2020 and 2030. More complete results can be found in Annex 4.A6.

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Table 4.5. **Road new construction requirements**

Region	2000 USD-B and (% GDP)	2010 USD-B and (% GDP)	2020 USD-B and (% GDP)	2030 USD-B and (% GDP)
Industrialised				
OECD	98.7 (0.31%)	159.4 (0.44%)	167.1 (0.37%)	178.1 (0.32%)
Non-OECD	1.7 (0.05%)	8.6 (0.22%)	9.5 (0.19%)	13.1 (0.21%)
Developing				
Big 5	9.3 (0.07%)	36.6 (0.19%)	46.6 (0.17%)	64.7 (0.16%)
Others	5.0 (0.08%)	15.7 (0.20%)	22.0 (0.21%)	36.4 (0.26%)
World	**114.8** (0.21%)	**220.3** (0.33%)	**245.2** (0.28%)	**292.3** (0.25%)

These road new construction estimates of between USD 200-300 billion/year over 2005-30 are considerably higher than the 2000 base year levels, and comparable in order of magnitude to the previous forecast of Fay-Yepes (USD 260 billion/year for 2005-10). As already noted, the latter was based on a roughly equal ratio of net additions to the capital stock and replacement capital requirements. This forecast models a much higher requirement for replacement (*i.e.* maintenance) construction spending.

Replacement construction to maintain the existing capital stock value is particularly important in countries/regions that have large base year stocks of road capital (especially former communist states of Europe and Central Asia[22]). With respect to the former, the significant additional new construction requirements (over base year spending) are relatively evenly split across regions between OECD-industrialised, Big 5 and developing countries, with relatively little coming from non-OECD-industrialised countries. The future consequence of rebuilding depreciated existing assets is not reflected in the base year new construction figure – indicating that most governments are still engaged in practices ingrained during the 1980-90s when capital expenditures and maintenance budgets were generally squeezed very hard to deal with public debt/deficit challenges.

To put these forecasts of road new construction into perspective, it is worth remembering that the postwar construction of industrialised country road networks largely occurred over a 40-year period from 1945-85, so that the 30-year time period considered here may witness comparable road network construction in some of the rapidly growing and more prosperous Big 5 and developing countries of the world (*e.g.* China).

There is some risk that the future new construction requirements in Table 4.5 may be too high. Certainly there has been no conscious effort to force "sustainability" and climate change (*e.g.* greenhouse gas, GHG) targets onto the road sector, although there has been some attempt to place upper-bound limits on road capital asset-to-GDP ratios. As GDPpc grows across the "threshold" value of USD 5 000 per capita in many countries (*e.g.* China) there will be enormous social/consumer pressures for vehicle ownership and road infrastructure responses, which will be extremely difficult to dampen.

A substantial amount of the initial "upward drift" in the new construction (as a percentage of GDP) results from the model assumption that countries will seek to "converge" toward industrialised ratios of road capital stock-to-GDP – even as these decline among industrialised countries. It may well be that the fiscal challenge to finance this rate of new construction spending will lose out to other public/private spending and investment options. However, it should be noted that the increased Big 5, developing and non-OECD-industrialised new construction rates (percentage of GDP) remain significantly below OECD-industrialised rates – and that the road capital stock-to-GDP ratios also remain well below OECD-industrialised ratios. In fact, it must be remembered that the actual road capital stock-to-GDP ratios *fall* for all regions – which reminds us that there are inevitable future costs just to maintain existing large stocks of road capital.

If there is one aspect of the road model that may overstate new construction forecasts of requirements, it may be how the replacement capital requirement is estimated. The model has effectively assumed that 1/30th of the 10-year lagged road capital stock must be replaced per year. Better minor maintenance practices and management could make that an overstatement.

The road capital stock value consistent with these results grows from USD 5 370 billion in 2000 to USD 7 130 billion in 2030, a cumulative growth of only 33% over 30 years. The ratio of road capital stock-to-GDP falls from 9.7% to 6.1% over this period, so the overall elasticity and observed downward trend of this ratio is certainly captured (for industrialised countries). The corollary of these results is that the productivity of road infrastructure continues to rise.

Ex post *elasticities for road capital stock*

This model began with the *ex ante* Fay-Yepes-type elasticities (with respect to GDPpc) of 0.25 (high-income countries) and 0.15 (low-income countries). However, two significant modifications have been made: *a)* to adjust for rising road new construction costs (per route-km); and *b)* with convergence over time towards high-income ratios of road capital stock to GDP.

The application of these adjustments resulted in *ex post* elasticities (with respect to GDP) for the entire 2000-30 period of: 0.20 (high-income countries);

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0.64 (Big 5 countries); and 0.76 (developing countries).[23] Not surprisingly, the adjustment factors had little impact for high-income countries, but significantly higher PRCS impact for Big 5 and developing countries.

There is no logical inconsistency between the *ex ante* and *ex post* elasticities. The *ex ante* Fay-Yepes elasticities represent what was actually experienced over the past three decades, during which there is every reason to believe that there was substantial underinvestment in road capital stock among developing countries. This is the thesis (supported by empirical evidence) from Canning-Pedroni. The convergence adjustment for developing countries is here *normative*, and represents what needs to occur in order to provide one of the necessary preconditions for rapid economic growth for the Big 5 countries, and for some of the faster-growing developing countries.

Risk factors for road new construction

The results above are based on economic drivers and assumptions, and do not reflect "wish lists" based on engineering needs. However, as already noted, there are many factors that might prevent (if desirable) or render unnecessary (*i.e.* make undesirable) the forecast levels of new construction on roads.

These include:

- Conscious government policy to constrain/reduce public expenditures – particularly focused on road new construction (but separate from "sustainability" concerns which are addressed next):
  - ❖ Up to (perhaps) 20% of the road new construction (*i.e.* USD 40-60 billion/year) could be diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality (*i.e.* as experienced during the 1980-90s) and higher road congestion (especially in urban areas).[24]
- Conscious government policy to shift transport infrastructure spending and use away from road-vehicles toward rail (including high-speed rail):
  - ❖ Up to (perhaps) 10% of the road new construction (*i.e.* USD 20-30 billion/year) could be so diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality.[25]
- Land use and environmental limitations on road infrastructure expansion, although most of the road new construction is driven from replacement requirements to maintain an existing stock of road capital.
- Improvements in road maintenance and management (especially efficiency enhancements through ICT/telematics, and extension of infrastructure life):
  - ❖ Up to (perhaps) 5% of the road new construction (*i.e.* USD 10-15 billion/year) could be saved in the long run.

- Reduced safety and security requirements (which appear unlikely). Generally, with the exception of in-vehicle communications/navigation/tracking technologies, these concerns are unlikely to add substantially to road new construction requirement (especially as road safety is a major influence in road design).

Conversely, there are factors that might increase the requirement for new construction on roads. These include:

- Increased costs associated with road construction in urban and congested traffic areas (*e.g.* right-of-way acquisition, environmental mitigation, integration with other infrastructures). Generally, it is believed these are factored into the model.
- Greater than anticipated geographic (spatial) dispersion of economic activity, especially in Big 5 and developing countries. It is difficult to imagine greater spatial dispersion occurring within existing industrialised countries, but such a phenomenon might occur within the larger of the Big 5 and developing countries (*e.g.* China, Russia, Brazil).
- Higher than anticipated growth in vehicle ownership and traffic use. Generally, a flexible upper-limit has been placed on vehicle ownership (vhp) and average distance driven per vehicle (adv). These might not hold, which would put further upward pressure on road construction.

Rail infrastructure requirements

Table 4.6 summarises the key estimates for rail new construction for the years 2000, 2010, 2020 and 2030. More complete results can be found in Annex 4.A7. It must be noted that the rail model was based on the road model and involves weaker base year data and significant manual adjustment to reflect known rail spending plans for China and OECD/EU-Europe.

These rail new construction estimates of between US$50-60/year over 2005-30 are only somewhat higher than the 2000 base year levels, but are substantially greater than the previous forecasts of Fay-Yepes. The latter forecast annual investment requirements of about USD 17 billion/year over 2005-10, and did not appear to reflect the significant rail upgrading plans envisioned and commenced under the EU TEN-T programme.

The significant additional new construction requirements (over base year spending) are primarily driven by Big 5 countries (especially China, which has committed to a major rail-building programme, including high-speed rail).

There is some risk that the future rail new construction requirements in Table 4.6 may be too low. Certainly, there has been no conscious effort to force additional "sustainability" and GHG targets by shifting traffic from road to rail – except to the extent this is built into the EU TENT-T programme.

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Table 4.6. **Rail new construction requirements**

Region	2000 USD-B and (%GDP)	2010 USD-B and (%GDP)	2020 USD-B and (%GDP)	2030 USD-B and (%GDP)
Industrialised				
OECD	26.9 (0.09%)	31.1 (0.09%)	34.3 (0.08%)	33.4 (0.06%)
Non-OECD	0.8 (0.02%)	2.3 (0.06%)	2.5 (0.05%)	3.4 (0.06%)
Developing				
Big 5	4.4 (0.03%)	12.2 (0.06%)	13.3 (0.05%)	15.0 (0.04%)
Others	1.9 (0.03%)	3.5 (0.04%)	3.4 (0.03%)	6.3 (0.04%)
World	**34.0** (0.06%)	**49.0** (0.07%)	**53.5** (0.06%)	**58.1** (0.05%)

The rail capital stock consistent with these results grows from USD 631 billion in 2000 to USD 1 342 billion in 2030, a cumulative growth of 110% over 30 years. The ratio of rail capital stock-to-GDP increases slightly from 1.1% to 1.2% over that period, which is only impressive in light of the downward trend of this ratio for road capital stock (for industrialised countries).

Risk factors for rail new construction

The results above are based on very subjective assumptions, which might reflect "wish lists" to the extent that these are embedded in EU TEN-T programme and Chinese plans for railway expansion. Unlike road construction – for which there is a clear consumer-revealed preference through autonomous traffic growth and vehicle ownership – rail construction is largely driven around the world by government policy.[26]

There are many factors that might prevent (if desirable) or render unnecessary (*i.e.* make undesirable) the forecast levels of new construction on rails. These include:

- Conscious government policy to constrain/reduce public expenditures – (and clearly antagonistic to "sustainablility" concerns which are addressed next):
  - Up to (perhaps) 20% of the rail new construction (*i.e.* USD 10-12 billion/year) could be diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall rail infrastructure quality and continued modal shift toward road vehicles (as perhaps did happen inadvertently over 1970s-90s in many countries).[27]
- Land use and environmental limitations of rail infrastructure expansion, especially the difficulty of right-of-way access around urban areas.

- Improvement in rail maintenance and management (especially efficiency enhancements and extension of infrastructure life):
  - ❖ Up to (perhaps) 5% of the rail new construction (*i.e.* USD 3 billion/year) could be saved in the long run.
- Lower-than-anticipated growth in HSR use and rail freight traffic.

Conversely, there are factors that might increase the requirement for new construction on rail infrastructure. These include:

- Conscious government policy to shift transport infrastructure spending and use away from road vehicles toward rail (including high-speed rail):
  - ❖ Up to (perhaps) 10% of the road new construction (*i.e.* USD 20-30 billion/year) could be diverted from road to rail infrastructure, with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality (*i.e.* as experienced during the 1980s-90s) and higher road congestion (especially in urban areas).
  - ❖ Up to (perhaps) a further 15% of rail construction (USD 5-10 billion/year) could be added if non-EU countries embraced high-speed rail (*e.g.* United States, Canada) during this period.
- Increased safety and security requirements. Additional tunnel, access, security and monitoring systems could add up to 5% of additional rail new construction requirement.
- Increased costs associated with rail construction in urban and congested-traffic areas. It is believed these are factored into the model.
- Higher-than-anticipated growth in HSR use and rail freight traffic. One optimistic forecast for passenger modal shift for Western Europe (over 2000-50) predicted a decline in daily travel distance by car (from 35 km to 20 km) and an increase in daily travel distance by air/HSR (from 5 km to 70 km).[28]

Benefits of transport infrastructure

There are several implicit assumptions related to anticipated benefits that are embedded in the approach and model of transport infrastructure requirements over the period to 2030[29]:

1. The bulk of existing transport infrastructure (in place in 2000) is cost-beneficial to maintain, and to marginally improve in terms of quality (*i.e.* rising replacement cost per route-km).
2. Most of the transport infrastructure investments over the past 20 years have been cost-beneficial, and it is very that likely some amount of cost-beneficial new construction has been constrained by public finance availability (*i.e.* trends in infrastructure spending to GDP, and capital stocks to GDP have been close to "optimal", if somewhat sub-optimal).

3. While political factors may have resulted in some uneconomic projects proceeding, and some reorientation of priorities, the aggregate transport infrastructure profiles reflect economic principles (*i.e.* are cost-beneficial).
4. Generally, there has been chronic under-funding of transport (and other) infrastructure in most Big 5/developing countries, reflecting public finance availability (despite IFI and donor country lending/grants).[30]

These assumptions allow us to invoke the following lemma: that transport infrastructure requirements estimated on the basis of historical relationships between road capital stock and GDP will also be cost-beneficial – so that the benefits of road infrastructure spending will exceed their costs.

Therefore, the model forecasts of road transport infrastructure requirements (in terms of cost) – namely USD 220-290 billion per year over 2000-30 – also represent a conservative estimate of the expected benefits of such transport infrastructure investments.[31]

A similar (but different) assumption may be made about rail transport infrastructure requirements (USD 49-58 billion per year), as much of this is driven by government policy to effect a deliberate modal shift (at the *margin*) from road to rail, to: *a)* achieve environmental/sustainability objectives and benefits; and *b)* to manage rising congestion and postpone future road infrastructure needs. Therefore, the benefits from rail transport infrastructure requirements will involve a lesser degree of economic benefit (in terms of productivity/GDP growth), and a greater degree of environmental/social benefit (likely *not* reflected in productivity/GDP growth, as currently measured).

Productivity/utilisation of transport infrastructure

A combined (freight and passenger) forecast over 2000-30 of 2.9% annual growth in vehicle transport use (vkm) has been produced – largely driven by rising vehicle ownership (as GDPpc rises), growth in underlying GDP, and assumptions about annual per-vehicle use.[32]

Over the 2000-30 period, the model (vkm growth relative to GDP growth) indicates that road-use intensity (to output flow) will rise about 0.4% per annum.[33] A similar measure (vkm growth relative to road asset value) indicates that road-use intensity (to capital stock) will rise about 1.3% per annum.[34]

Other studies have looked at intensities of freight (tkm/GDP) and passenger (pkm/GDP) transport and found:

- For the United States (over 1960-98) a falling ratio of road ton-miles per $GDP.[35]
- For other industrialised countries (over 1970-98) mixed results with: a falling ratio of road tkm per $GDP for Japan and the United Kingdom; a relatively stable ratio for Germany; and an increasing ratio for France and Sweden.[36]

- For the United States and Japan (over 1970-2000) a falling ratio of passenger transport, while for the EU rising passenger ratios, and relatively stable ratios for freight.[37]

In the absence of reliable cross-country data on freight (linking tkm to vkm by country) and passengers (linking pkm to vkm by country), there is no attempt to forecast freight (tkm) or passenger (pkm) transport volumes. It could be speculated that vkm growth (over 2000-30) will be higher than underlying pkm growth, since passenger occupancy per vehicle generally falls as vehicle ownership rates rise with rising GDPpc, and since freight growth might outstrip population growth. It could also be speculated that vkm growth (over 2000-30) will be lower than underlying tkm growth, as the latter (but not the former) is influenced by rising vehicle ownership rates, as the size/weight of trucks increase with GDPpc growth (and better-quality roads), and as freight distances grow with industrialisation, specialisation and intensive trade/supply chain complexity.

3. Impact of key drivers on future surface transport demand

As discussed in the previous section, there are clear upside and downside risks (or pressures) that would influence the road and rail capital stock and new construction forecasts to 2030. This section addresses the following factors:

- Modal split and shift from road to rail.
- Freight *vs.* passenger transport growth.
- Information and communications technologies (ICT).
- Road capacity utilisation.
- Road pricing.
- Spatial distribution/population density.
- Security and climate change risk.
- Country-specific and regional variation.
- Demographic factors.
- Public capital constraint as a limit on surface transport.

Modal split – shift from road to rail

A natural "policy experiment" was undertaken during the 1980-90s to put the macroeconomy and public finance on a more stable and growth-oriented basis. This policy experiment involved significant curtailing of public capital spending in many areas – particularly in transportation. The subsequent slowdown in productivity growth, rising work-time pressures and growing road congestion suggest that the "do-nothing" approach to effect modal shift from road to rail – by hoping that enough road congestion will force commuters/ passengers to rail – does not work in the absence of improvements to rail (and public transit) infrastructure.

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While *public* investment in road infrastructure was curtailed in most countries (the United States being a possible exception), *private* investment in road vehicle ownership and spending to sustain road use grew. This was despite growing awareness of environmental and sustainability concerns and problems from growing automobile dependence and use.

In order to fundamentally alter the future land transport growth (as forecast here), a very substantial amount of land transport infrastructure investment will need to be diverted from road to rail infrastructure – in urban areas (for commuters) and in intercity freight and high-speed rail capacity. What makes this difficult to envision and implement is that it is very likely over and above the significant existing commitments in China and the EU-OECD for railway (and HSR) upgrading – and would still require a very substantial increase in road construction spending. There is no "sustainability" fiscal dividend involved. Public finance and transport authorities will be spending more on road infrastructure than currently – but there is a margin of land transport infrastructure investment that can be shifted from road to rail infrastructure.

The biggest challenge will be in urban areas – where additional rail-track capacity is often very difficult and expensive and involves local amenity issues (*e.g.* NIMBY). The latter also exist for road infrastructure. Rapid urbanisation growth in the Big 5 and developing countries will require large investments in road and rail infrastructure. Roads are far more flexible (in terms of route choice) for most suburban commuters, and the urban rail network must be extensive (with relatively high urban housing/population density to support it).

The (general) political unpalatability of road pricing has meant that decentralised local-based funding and decision-making models have not been capable of rapidly expanding urban rail networks. There is a need for higher-level government planning and funding support, whether or not private partnership is invited.

Rising fuel prices have been shown to affect both road and rail use (this depends somewhat on the degree of rail electrification) – although passenger and freight traffic are remarkably fuel-price inelastic in the short term.

Over the 2000-30 period, there are no breakthrough technologies that will fundamentally affect land transport demand. High-speed rail (and Maglev) technology is around and tried. Improved vehicle technology (*e.g.* fuel efficiency, fuel technology) and vehicle design can offer substantial environmental benefits. Improved road/rail infrastructure management will be achieved through ICT (*e.g.* advanced vehicle guidance systems, network management systems), which will boost transport infrastructure productivity and have a marginal dampening effect on future infrastructure requirements.

Security and safety concerns may run counter to environmental concerns. Additional security/safety costs will probably need to be built into rail systems to counteract security/traveler concerns. It is unclear whether (relative to air) there is a clear security/safety benefit for high-speed rail.

Regional integration and international connectivity demand that rail systems be capable of meeting long-distance freight requirements (where rail still has a natural advantage), and that road systems are adequate for shorter-distance freight and passenger movements. History has shown that road transport linkages have been more important than rail, although our understanding (and decomposition) of traffic flows allows for a more sophisticated approach on a corridor basis.

Investments in other transport infrastructures (air, ports, inland water) are also required, although there is some trade-off potential between air and land transport for medium-distance high-speed rail (with sufficient population density and gravity-interaction between nodes), and between inland water and rail for medium-distance freight movements. There is also considerable complementarity between land transport infrastructure and access to ports/airports, which act as respective international (long-distance) transport hubs. Road and rail connectivity to airports/ports is critical to growing international movements – and there is a danger in many cities that local planning and amenity issues could override national/international interests in improving these connections. Better methods to balance local/regional with national/international interests and concerns are critical – and for this the EU TEN-T process has been exemplary.

Freight vs. *passenger transport growth*

Historical analysis shows that there is a strong statistical correlation between the growth of GDP and transport, both passenger and freight – even though there may be significant variation in the relationship between freight tkm/GDP across various individual countries.[38]

Several factors are influencing (industrialised country) traffic growth:[39]

1. An indeterminate change in freight transport elasticity (relative to GDP) over the past ten years due to three intersecting factors:
   - Reduced trade barriers (*i.e.* globalisation) and increased international transport – which are increasing freight intensity.
   - Reduced material (especially weight) requirements in goods – which are decreasing freight intensity.
   - Decreased proportion of GDP comprised of goods *vs.* services – which is decreasing freight intensity.
2. A decline in passenger transport elasticity (relative to GDP) over the past ten years, due to population ageing.[40]

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Freight transport

There is clear evidence from trade/traffic data that average km-distance traveled is growing – so that tonne-km and freight vehicle-km are growing faster than tonne-km – and that this is particularly concentrated in key corridors of national/continental networks.[41]

Freight traffic must deal with modal split (especially road-rail) which is typically distance-related and time-sensitive. Road is more cost-efficient for short haul (perhaps up to 500 km), while rail is more cost-efficient for long haul (over 500 km). Time-sensitive goods are more likely to be moved by road, which is more flexible in terms of routeing, door-to-door delivery, and journey scheduling.

While there is considerable interest in the issue of "decoupling" transport (and related energy-use) growth from economic growth, there are many factors operating to mediate between GDP growth and freight transport growth:

- The relative importance of services (versus goods), whose production and sales are less freight transport-intensive (although services may be more passenger transport-intensive).
- The relative reduction in material content/weight per dollar value of goods.
- The relative importance of international (and inter-regional) trade (versus local commerce), which involves longer distances and greater freight-transport intensity.
- The relative importance of production specialisation (and complexity of supply chain management), which may involve greater spatial distribution of supply chains, longer distances and greater freight-transport intensity.

The first and second factors may (in a long-term steady state) result in a lower freight-transport intensity (and global freight transport growth lower than global GDP growth). However, with continuing elimination of trade barriers (*e.g.* WTO agricultural trade barriers), the emergence of Big 5 countries as major economic powers (on both production and consumption sides of the economy), and rapid technological change among all "emerging" developing countries, the third and (especially) fourth factors are likely to dominate the evolution of global freight-transport intensity over the 2000-30 period.

The model here does not explicitly forecast freight transport use. It does forecast vehicle use (freight and passenger), based on vehicle ownership and annual distance driven, to grow at the same 2.9% annual rate as GDP – implying an elasticity of vehicle use of 1.0 over 2000-30.

A summary of relevant freight elasticities indicates that a range from 0.7 to 1.5 has been observed historically in industrialised countries, with a recent OECD average of 0.8. However, most of these estimated are for combined freight (mostly road and rail). Against this is the possibility that the Big 5/developing countries could experience higher freight elasticities, perhaps in the 1.5-1.8 range experienced by industrialised countries in the earlier 1950-70s period.

Table 4.7. **Relevant freight elasticity relationships**

Study	Variable	Elasticity
1. Road and rail freight		
Meersman-Van de Voorde (2003) selected EU countries (1990-2000)	GDP	Range from 0.7 (France) to 1.5 (Denmark), with most estimates in narrower range of 0.9-1.4
Landwehr-Marie-Lilleu (2002) OECD (total freight, 1986-97)	GDP	OECD 0.8 – with range of 0.8 (North America, Japan) to 1.3 (Western Europe)
Tsamboulas (nd) EU accession countries (2000-20)	GDP	Forecast of 1.6
WBCSD (2004) Global (2000-30)	GDP	Forecast of 0.83
Landwehr-Marie-Lilleu (2002) Global (2000-30)	GDP	Forecast of 0.63
2. Road freight		
AU-BTCE (1990) Australian Corridors	GDP (real income)	Range from 1.0 to 2.0, with higher value generally for dense long-haul routes
Song *et al.* (1993) selected industrialised countries (1950-70s)	GDPpc	Range from 1.4 to 2.5, with most estimates in narrower range of 1.5-1.8

Passenger transport

Because local transport accounts for more than 80% of traffic in most countries, urban sprawl has a major impact on trends in personal/commuter passenger traffic; an increasing proportion is based on multi-purpose travel chains. Another major segment of passenger transport is "leisure/tourism" which takes place over medium to long distances and which is heavily influenced by GDPpc lifestyle factors such as increased leisure time; more frequent but often shorter trips; and diversification of leisure (*e.g.* visiting friends and relatives, cultural, educational).

Passenger traffic (*e.g.* traveler mobility) is influenced strongly by:[42]

- *Car ownership* – where rates have increased much more quickly than income levels and population age structure suggested (*e.g.* multiple car ownership).
- *Population ageing* – where this is slowing the increase in short-haul (local) transport.
- *Family structures* – where increasing single-parent families are reducing vehicle occupancy levels and group travel sizes.

Factors operating to mediate between GDP growth and passenger transport growth are:

- Rising vehicle ownership rates, especially with national GDPpc rising through the USD 5 000 "inflection point" (where vehicle ownership accelerates).
- Urban spatial distribution (density *vs.* sprawl), which support (or limit) the efficiency/viability of rapid public transit as an alternative to private vehicle use.

- Social factors (*e.g.* ageing population, family structure, migration patterns), which support (or limit) the private vehicle trip use (relative to time-choice, and local *vs.* non-local accessibility to family/activities/etc.).

The first factor is dominant in some Big 5/developing countries and will result in higher passenger-transport intensity (*i.e.* faster than national GDP growth), and be supported by the third factor (*e.g.* younger population, greater international/regional migration). For many industrialised countries (where vehicle ownership rates are flatter), the third factor (especially ageing of the population) may reduce passenger-transport intensity – although this will be highly related to the second (urban spatial distribution) factor – and the availability of public transport alternatives.

A summary of relevant passenger elasticities indicates that a range from 0.6 to 1.4 has been observed historically in industrialised countries, with a recent OECD average of 1.0. Against this is the possibility that Big 5/developing countries could experience higher passenger elasticities, perhaps in the 1.5-2.0 range experienced by industrialised countries in the earlier 1950-70s period.

Table 4.8. **Relevant passenger elasticity relationships**

Study	Variable	Elasticity
1. Road and Rail Passenger		
Landwehr-Marie-Lilleu (2002) OECD (1986-97)	GDP	OECD 1.0 – with range of 0.6 (North America) to 1.4 (Western Europe)
Tsamboulas (nd) EU accession countries (2000-20)	GDP	Forecast of 1.0
WBCSD (2004) Global (2000-30)	GDP	Forecast of 0.53
Landwehr-Marie-Lilleu (2002) Global (2000-30)	GDP	Forecast of 0.43
2. Road passenger		
Song *et al.* (1993) selected industrialised countries (1950-70s)	GDPpc	Range from 1.1 to 2.3, with most estimates in narrower range of 1.5-2.0
Johansson-Schipper (1997)	GDP	Range from 0.7 to 1.3, with best-guess of 1.2

Information and Communications Technologies (ICT)

A study of the impact of ICT on transport found that advanced vehicle technologies have the future potential for automated driving, which (along with improved road network management technologies) holds promise for increasing transport safety and capacity.[43] There is no doubt that, over the 2000-30 period, continued vehicle and energy-efficiency technology improvements will shape transport energy use and driver behaviour. However, it is not expected that technology will fundamentally affect the growth of passenger transport (relative to the impacts of rising income, GDPpc and vehicle ownership).

There are likely to be ICT-inspired improvements in road capacity utilisation – but these will operate at the margin of incremental demand, and will not substantially impact the overall road infrastructure requirements (rising from GDP, population, vehicle ownership growth; increased urbanisation; urban development – except as mediated by urban density/spatial distribution/road pricing policies around land use).

Generally, the broad literature on the interaction of ICT and transport suggests that these are complementary (rather than substitutes); the potential for ICT to change travel patterns, times of day, choice of destinations, etc. may distribute anticipated demand increases over time and (potentially) reduce peak-hour urban-road congestion.

Road capacity utilisation

Typically (over time) we often see new road infrastructure installed in anticipation of future traffic growth. Significant periods of new road construction (*e.g.* North America over 1950s-70s) result in periods of low capacity utilisation, followed by steady increases in traffic relative to additional road capacity, resulting in rising capacity utilisation. This has been observed at national/regional levels as well as in urban/suburban areas. New construction infrastructure spending is usually motivated by one (or more) of the following factors:

- National security/sovereignty and/or regional integration (*e.g.* accessibility to remote border regions).
- Land development (*e.g.* new towns, suburbs, industrial areas, resource access, major facilities).
- Road congestion due to traffic growth (passenger, freight) beyond the existing road capacity.
- Safety improvements (*e.g.* passing lanes, shoulders, realignment, barriers, signage, level-crossing elimination).
- Environmental improvements (*e.g.* flood control, damage mitigation, noise reduction).

The important point to make is that traffic-related road congestion is one of five drivers for new construction, although it is typically a more important factor in determining benefits (from time-savings) than are safety/environmental benefits. Typically, the first two (non-congestion) factors have played the largest roles in major national transport infrastructure development.[44]

ICT-inspired improvements in road capacity utilisation are anticipated (*e.g.* network management, accident response, driver information, automated

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driving advances). However, such improvements will have only modest impacts on road infrastructure requirements because:

- In industrialised countries, most road infrastructure requirements are generated from replacement (maintenance of depreciation) needs.
- In many Big 5/developing countries, most road infrastructure requirements are generated from urban/land development and regional integration needs.

Road pricing

The policy of road pricing has two aspects: *a)* as a sustainable source of infrastructure pricing and funding (as part of an overall transport infrastructure management/governance approach); and *b)* as a means to influence mode-choice and properly incorporate externalities into consumer travel decisions. There is no doubt that own-price and cross-price elasticities for freight and passenger transport are positive; and that increased (relative) costs of road use will result in a marginal shift from road to rail (for freight/passenger) and other public modes (for passengers).

The behavioural impact strength of such elasticities remains an empirical question, relative to: the overall income elasticity of road freight/passenger transport; the availability/capacity/service levels of the alternatives; and other factors (such as urban density/spatial distribution, vehicle ownership rates).

There is no doubt that a combined (and concerted) policy involving land-use/spatial distribution/urban density; road-pricing; ICT-inspired improvements in road capacity utilisation; and infrastructure improvements in rail/public modes would have a noticeable and (relatively) significant marginal impact on the need for road infrastructure requirements. There is, however, no certainty that the political constellation(s) will support such a holistic policy package – not least as many decisions must be jointly enacted by different levels of governments and require considerable time to build policy consensus.

Spatial distribution/population density

Perhaps the most difficult policy to gain political approval involves (more compact) spatial distribution and (higher) population density – especially within/between major urban areas. Besides the difficulties of achieving public consensus and political co-ordination, there is the path dependency of urban forms. If infrastructure is best viewed as a system, there is no more complex system than the urban form – comprised of overlapped multi-generational, life-cycle decisions related to migration, urban location, housing choice, employment opportunities, transport choices and decisions, lifestyle choices, etc. The current spatial urban forms of cities as diverse as London, Paris, New York, Houston, Sydney, Tokyo, Hong Kong, etc. have developed over centuries, and while they can be shaped/

influenced (both at the margin and intensively) over several decades, such change is often costly, disruptive, chaotic, politically divisive, etc. and often limited to specific sub-areas of the overall urban form.[45]

There is no doubt that more spatially compact and densely populated nations and urban areas support very high volumes of freight and passenger transport within limited, congested urban road networks and extensive public transport systems. Generally, such urban congestion and density mean that transport infrastructure is highly integrated with other urban infrastructure systems (*e.g.* telecommunication, water/sewer, energy); maintenance and added capacity are very expensive. Thus, while measures of road capacity utilisation are much higher, the dollar cost of road infrastructure (per km) is much higher as well.

A particularly important issue from the perspective of integration infrastructure system planning relates to right-of-way acquisition and protection (from encroachment). Within urban areas (especially) there is a need for long-term planning to ensure that urban spatial growth will be adequately and efficiently managed by infrastructure investments, along dedicated infrastructure rights-of-way, and in an integrated manner.

Encouragement of greater density within existing urban areas would (likely) have a moderate impact on reducing road infrastructure requirements, although such an achievement would require a holistic policy package, including significant urban transport infrastructure investment.

Security and climate change risk

Overall, measures to manage security risks, increase transport security and address climate change would have a marginal to moderate impact on increasing road infrastructure requirements. Some of this would likely be embedded in various ICT improvements in road capacity utilisation, and new construction requirements to address safety/environmental issues.

Perhaps the biggest risks over 2000-30 are the impacts on road and rail networks (national/regional/urban) that could arise from: *a)* natural disasters (*e.g.* earthquakes); and *b)* rising water levels (and flood risk) from global warming. While the former is a risk factor built into transport infrastructure management in many countries/regions of the world, the latter is a more recent issue to arise, and has not been systematically assessed in terms of risk management (exposure/impact). Many large urban centres are at sea level, making rising ocean levels a long-term threat. Climatic disturbances (*e.g.* affecting rainfall levels/ patterns) may also result in unanticipated flooding of certain links in national/ regional transport networks, and unanticipated changes in freeze-thaw cycles affecting infrastructure integrity and maintenance costs.

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Country-specific and regional variation

The base-year regional/development groupings used in the model for this study reflect cross-country aggregation of national-level data. There are considerable regional/national variations in road/rail networks, vehicle ownership, infrastructure capital value and GDP growth that are built in.[46]

The model relies principally on road/rail transport infrastructure capital stock elasticities with respect to GDPpc (with adjustments for: *a)* increasing road quality over time in route-km costs; and *b)* convergence in transport infrastructure spending [as a percentage of GDP] towards industrialised levels), and associated road-use elasticities with respect to GDP (and GDPpc for vehicle ownership). While the model growth parameters are insensitive to other factors (*e.g.* spatial distribution, population densities, demography), such factors are reflected in the base-year disaggregated national data, on which the growth is based. Therefore, the model does incorporate base-year variations in such models, even if it does not allow for growth rate variations (other than GDP growth and GDPpc levels). The underlying growth rate assumptions (*e.g.* World Bank for GDP growth, UN for population growth) would themselves have recognised, and taken into account the impact of some of these factors.

Excluded are any sub-national variations that would affect the distribution of population, economic activity and transport activity within countries. This is the inevitable price of a global focus and aggregation ability, as well as availability of suitable data.

Demographic factors

There is no doubt that demographic factors (principally the population ageing in most industrialised countries) will impact future transportation infrastructure requirements. While the model does not explicitly deal with such factors, they are embedded in the base-year data and in the underlying growth rate assumptions (from World Bank and UN sources).

It is assumed that the bulk of demographic changes are captured in the model through GDP and population growth (which are considerably lower in industrialised countries with low population growth and population ageing), and through the “convergence” adjustment relating transport infrastructure stock (as a percentage of GDP) towards industrialised levels.

Population ageing has been observed in many industrialised countries since the 1980s, so the trends observed (and incorporated in this model) – *a)* slowing growth in vehicle ownership rates; *b)* little/no growth in annual vkm per vehicle; and *c)* declining rate of road capital stock (as a percentage of GDP) – are felt to adequately capture the future impact of demographic change on road/rail transport use and infrastructure requirements.

Public capital constraint – limit for surface transport

A major factor impacting whether transport infrastructure requirements are met is the public willingness to pay for increased land transport mobility – either through general taxation (as mediated by public finance authorities), specific taxation (where this exists) or user-charges (including in support of private participation, *i.e.* PPP). Road users (direct and "indirect") are a lot like taxpayers in general – so the finance issue should be, what is most publicly palatable to fund required transport infrastructure? Unfortunately (for land transport authorities), the concept that there should be a "price" for public capital access and that such revenue should remain within the land transport sector appears to be rejected (or overridden) by other public finance "principals" and spending priorities.[47]

The ageing of the world population (at least in industrialised regions) will put pressure on health care systems and lead to many competing policy pressures for limited public funds – especially with the apparent "cap" on taxpayer willingness to pay. The increasing conversion of taxes into user fees has (partially) provided a relief valve, but there has been limited public willingness to pay for (previously) "free" road access – and public finance authorities have not generally been willing to cede what they consider as "taxation power" to land transport authorities.

Land transport infrastructure (road and rail) has a very long economic life (30+ years) – and capital planning and budgeting requires a lengthy (10- to 20-year) cycle that clearly conflicts with 7-year business cycles, 3- to 5-year political cycles and 2- to 3-year budgetary cycles. Any time there is a short-term crisis, long-term plans for land transport infrastructure funding will be sacrificed for short-term expediency. As the experience of the 1970-90s showed in many countries, it is politically possible to starve public capital for a long time before the public starts to notice.

The ability to balance stakeholder and political accountabilities makes the governance of land transport infrastructure systems (and their funding) difficult – requiring sustained political commitment over a considerable period (*e.g.* Swiss referenda on land transport). There are real dangers in over-investment in road transport infrastructure, in poor land use policies, in low-density urban sprawl, etc. It is difficult to manage these effectively except at the relatively local level – but with policy guidance, planning and co-ordination involving senior levels of government (*e.g.* regional, national, supranational).

Long-term investments require political and economic stability. The world inflationary and macroeconomic environment is currently very stable, although there are concerns over the US "twin deficits" (current account and public finance) for which there is no clear equilibrating mechanism.

4. Viability of current model for surface transport infrastructure

The EU TEN-T process has already been cited above as an exemplary model of transport infrastructure planning and inter-governmental consultation. However, the EU nation-state funding commitments and project timetables have not always been met, for all the reasons discussed in the previous sections.

The road and rail infrastructure (new construction) requirements forecast in Section 2 require substantial additional funds. The world annual road and rail new construction requirements could be in the order of USD 270-350 billion/year over 2010-30. This represents an enormous increase over the estimated current (2000) world spending of about USD 150 billion/year – even allowing for some efficiencies, deferred plans and possible overestimation.

Public sources of funds

Economic growth is driving most of these land transport infrastructure requirements, so that – provided there is proportional growth in public revenues – there should be sufficient public funds to finance most of the requirements. However, as stated above, there is general taxpayer resistance and political unwillingness to have tax revenues grow at the same pace as economic growth, and there are competing and very pressing public policy issues competing for scarce taxpayer funds (*e.g.* education, health care, poverty reduction).

The public revenue capacity to finance needed land transport infrastructure will be most difficult to obtain in the developing and Big 5 countries – where there may also be issues of tax avoidance/evasion, black markets and political corruption, which all undermine tax revenue generation.

However, the naïve belief that if the public sector cannot finance transport infrastructure the private sector will has been proved wrong, as many of the same problems that confound public finance also impact on private finance (*e.g.* inflation risk, political instability risk, contract risk). In fact, it is precisely those countries with the most "potential" for public revenue generation that are also the most attractive and have the greatest potential for private financing of transport infrastructure.

Clearly, therefore, there is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role and balance between the two.

Private sources of funds

Private investment in transport (and other) infrastructure over 1990-2001 was especially strong in Latin America – along with policies of deregulation, privatisation and other economic reforms – although the dollar volume of "greenfield" projects was greatest in the East Asia-Pacific region.[48]

These forecasts of road and rail transport infrastructure requirements suggest that the greatest opportunity for private financing of "greenfield" projects will be in China, and other Big 5 and developing countries.[49] At the same time, there will be considerable growth in the market for concessions and other "brownfield" packaging of existing (with some possible new) infrastructure in industrialised countries.

There are no easy solutions here. The challenge of transport infrastructure funding (and governance) involves a complex mix of public finance, political, economic, environment, and land use issues – with overlapping time frames, decision cycles, and deadlines.

Governance of infrastructure funding

One study that investigated the governance of transportation infrastructure financing mechanisms looked at international evidence pertaining to:[50]

- *Financing of infrastructure*, including: stability of funding; multi-year plans; range and composition of funding; degree of "user-pay"; borrowing power (*e.g.* issuance of bonds); analytical basis for capital/programme expenditures; range and scope of activities supported, etc.
- *Governance of funding mechanism*, including: selection and role of board of directors; oversight by government departments; oversight by parliament/legislature; transparency of reporting/evaluation; amount of information available from official Web site; guidelines for ethics/conflict of interest, etc.

The study found four types of transportation infrastructure financing mechanisms:

1. *Traditional grant programmes:* the mainstay of the public sector, usually of medium-term duration (up to five years) and subject to annual political appropriations control and review.
2. *Special-purpose funds:* involving dedicated user-pay revenue sources that provide multi-year funding stability and usually imply an indefinite, ongoing commitment – although these involve traditional (bureaucratic/political) governance.
3. *Commercial funding agencies:* involving some form of privatisation/commercialisation of the infrastructure and/or the establishment of a quasi-public agency to provide infrastructure funding on a (generally) commercial, self-financing basis (*e.g.* through repayable loans, revolving fund, user-pay), or long-term public revenue commitment.
4. *Innovative financing mechanisms:* which, by definition, do not fit the above three moulds, and cannot be characterised in terms of features.

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Some of the desirable features of well-functioning infrastructure funding mechanisms are:

- Clear objectives, stable multi-year operation, strategic/capital plans and project selection processes.
- Major user-fee revenue contributions.
- Strong local stakeholder involvement, government oversight, public transparency and evaluation/audit oversight.
- Reasonable balance between policy objectives of: *a)* efficiency, fiscal sustainability and environmental sustainability; *b)* high degrees of public/political support; and *c)* strong accountability for performance results.

Some of the innovative features of transportation infrastructure financing mechanisms are:

- Accrual public accounting for infrastructure cost, depreciation expense and financing costs (including appropriate return to the shareholder).
- Use of commercial borrowing as a funding source to encourage fiscal sustainability and demand fiduciary accountability for fund uses, better link accountability to performance, and better distribute benefits and costs.
- Use of user-pay pricing for heavy goods vehicles as a major aspect of revenue generation for infrastructure and "efficiency gain-sharing", and to effect modal shift (from road to rail) and/or full-cost user pricing to achieve efficiency and environmental sustainability objectives.
- Network-wide asset planning and project identification, and comprehensive asset management and performance measures.
- Involvement of local stakeholders in mechanism management, strategic planning and project selection, with high degrees of public transparency.
- Explicit criteria to promote inter-jurisdictional standardisation/interoperability of equipment-technologies-processes in infrastructure management.

5. Conclusions

Key drivers of land transport infrastructure (capital stock and new construction) are the relationships between, on the one hand, GDP and population growth (and GDP per capita growth), and on the other, measures of road use, vehicle ownership and paved-road capital stock – which are embodied in the elasticity between infrastructure (road and rail) capital stock and GDP per capita. Growth in GDP per capita results in higher vehicle ownership, more freight transport, more road traffic, and demand for road infrastructure. There is a relationship between paved-road capital stock (current and lagged) and new construction requirements. The latter include both new construction required for net additions to the value of the paved-road capital stock, and new construction to replace depreciation of existing (lagged) paved-road capital stock.

These key drivers primarily relate to road transport – and while they are also relevant for rail transport – rail use and infrastructure investment is much more controlled by public spending priorities and sustainability policy to affect modal shift from road to rail. Some of these priorities and policies are seen in existing government infrastructure plans (*e.g.* EU TEN-T projects, China's railway upgrading plan, Swiss transport policy).

Road transport infrastructure requirements (new construction) of between USD 220-290 billion/year over 2005-30 are estimated. These are comparable in order of magnitude to previous World Bank forecasts of Fay-Yepes. They are also a substantial increase above the estimate base-year (2000) level of investment of about USD 110 billion/year – so that their planning, financing and implementation will require considerable effort and challenge. A majority of these investment requirements do not result in net additions to the value of the paved-road capital stock, and are required to replace (*i.e.* maintain) the depreciating paved-road capital stock. These road infrastructure investment levels require a higher (than present) rate of spending (as a percentage of GDP) – although the ratio of the paved-road capital stock-to-GDP is consistently falling over time.

Rail transport infrastructure requirements (new construction) of between USD 49-58 billion/year over 2005-30 are estimated. These are greater than previous World Bank forecasts of Fay-Yepes. They are also a substantial increase above the estimate base-year (2000) level of investment of about USD 35 billion/year – so that their planning, financing and implementation will also require considerable effort and challenge. There is a more even split of these investment requirements between net additions to the value of the rail-track capital stock and replacements of depreciating rail-track capital stock. These rail infrastructure investment levels require a relatively constant (to present) rate of spending (as a % of GDP) – and the ratio of the rail-track capital stock-to-GDP is relatively stable over time.

There is considerable scope for deliberate government policy to influence modal use – and shift more road use to rail – through the diversion of up to 10% of road new construction (*i.e.* USD 20-30 billion/year) to rail (in addition to the levels of investment already forecast). These would have some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality and rising road congestion.

Whether vehicle ownership and road traffic use will remain as "constrained" as forecast here – and whether rail traffic will grow as fast as "hoped" – remain to be seen. Despite what public finance authorities may hope for, there is no "sustainability" fiscal dividend involved, so that public finance and transport authorities will be spending more on road infrastructure in the future. The shift is in terms of moderating the future increase in road infrastructure spending, not in its elimination.

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The biggest challenge will be the public willingness-to-pay for increased land transport mobility – either through general taxation (as mediated by public finance authorities), specific taxation (where this exists) or user-charges (including in support of private participation, *i.e.* PPP). Serious discussion is required by public finance/transport authorities and the public over an appropriate "price" for access to public capital, and how such revenue remains within the land transport sector (and is allocated between road and rail).

Somewhat perversely, the countries with the most "potential" for public revenue generation will also be the most attractive and have the greatest potential for private financing of transport infrastructure. The greatest opportunity for private financing of "greenfield" projects will be in China and other Big 5 and developing countries, while there is considerable scope for growth in the market for concessions and other "brownfield" packaging of existing (with some possible new) infrastructure in industrialised countries.

There are no easy solutions to transport infrastructure funding here. The challenge of that funding (and governance) involves a complex mix of public finance, political, economic, environment, and land-use issues – with overlapping time frames, decision cycles and deadlines. Clearly therefore, there is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role and balance between the two.

The ability to balance stakeholder and political accountabilities makes the governance of land transport infrastructure systems (and their funding) difficult – requiring sustained political commitment over a considerable period. There are real dangers in over-investment in road transport infrastructure, in poor land-use policies, in low-density urban sprawl, etc. It is difficult to manage these effectively except at the relatively local level – but with policy guidance, planning and co-ordination involving senior levels of government.

While it is tempting to focus on the absolute US dollar volume of land transportation infrastructure requirements to 2030, it is equally (if not more) important to assess the entire governance and accountability regime of land transportation infrastructure funding – and in particular, issues of funding stability, "user-pay", political and government oversight, transparency of reporting/evaluation, and accountability for performance.

Notes

1. OECD (2005), p. 10. That study noted that "methodological approaches are difficult to characterise and elucidate since only a few of the projections describe these in sufficient detail".
2. OECD (2005), p. 10. Studies with a broader range of forecast variables included UK-Royal Academy of Engineering (RAE) (2005) (*i.e.* ICT impact on transport efficiency); US-DoT (2000) (*i.e.* immigration impact); and DE-ifmo (2005)

(*i.e.* security impact; climate change/extreme weather impact). The rationale for a limited set of forecast variables include: parsimony (*i.e.* Occam's Razor); co-integration (*i.e.* joint determinism of variables); and impact uncertainty (*e.g.* absence of historical evidence).

3. Fay-Yepes (2003).
4. Andrieu (2005).
5. This mean estimate excludes the Canning value. The transformations are: GDP per capita elasticity is about 3.1 times the GDP elasticity (for GDP growth of 3% and population growth of 2%); and GDP per employee elasticity should be equal to the GDP per capita elasticity with a constant employment rate. The equation is $\xi_{pc} = \xi * [g(1+g)]/(p-g)$; where g is the GDP growth rate and p is the population growth rate.
6. Stevens-Michalski (1993), p. 1. This is for all forms of transportation.
7. Munnell (1993), Figure 3. Investment rates varied from 2-6% of GDP across OECD countries. If transport represents about 35% (as in the United States) of this investment, this would put the OECD range of road investment (*i.e.* new construction) at between 0.7 and 2.1% of GDP, with a mean of about 1.4%.
8. Munnell (1993), Table 2. Roughly 35% (1990) of US public (non-defence) public capital is road (highways and streets).
9. Evaluated for GDP growth rate of 3%.
10. Evaluated using the 3.1 ratio of GDP elasticity relative to GDP per capita elasticity.
11. Evaluated for GDP growth rate of 2.5%, base capital stock-to-GDP ratio of 12% (*i.e.* slightly lower than the US ratio), and assumptions that 35% of public investment is road transport, and 50% of that is for new construction.
12. Across a wide range of industrialised countries the ratio of 50% maintenance/50% new construction is often seen (more or less). The distinction between maintenance/ new construction is based on engineering criteria and the nature of the works involved, and not on life cycle asset management and asset value accounting.
13. Fay-Yepes (2003), Table 4. The equation also included an elasticity for population density (0.37 HIC; 0.46 L/MIC) and a coefficient on lagged asset value (0.28 HIC; 0.02 L/MIC).
14. Fay-Yepes (2003), Tables 5, 7. New construction costs were assumed to be about USD 0.41 M per km of two-lane paved road.
15. It should be noted that the author's starting paved road capital stock (2000) is USD 5 372 billion, compared to the Fay-Yepes value of USD 6 129 billion (*i.e.* 12% lower).
16. Canning-Pedroni (1999), p. 6.
17. Canning-Pedroni (1999), p. 31.
18. OECD (2004), Table 4, based on work by Johansson-Schipper (1997).
19. The Big 5 are China, India, Russia, Brazil and Indonesia.
20. Schipper and Marie-Lilliu (2001), Table 2; Zhongyuan *et al.* (2002), Table 3.5. The author's estimates for 2020 are: China-10.6; India-3.7 and Indonesia-3.8 – which are comparable for China, much lower for Indonesia, and much higher for India – although of a comparable magnitude.

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21. One major anomaly in the author's "received" data (from IRF) is the China estimate of annual distance driven per vehicle of 50 000 km (reported consistently over three years). This is much higher than the industrialised and most developing countries. The author uses that figure – with a continuous decline to 35 000 km per vehicle by 2030. To the extent that this remains an over-estimation (*e.g.* relative to likely 15 000 km convergence target), the vehicle-use result for China is overstated by a substantial amount (perhaps 50%). This has no bearing, however, on our other forecasts for vehicle ownership or road construction requirements.
22. Some of these countries/regions may in fact decide that they have over-invested in certain aspects of their road system, and may choose to allow some to deteriorate in quality. This model generally assumes that all replacement capital needs are met.
23. These are arc-elasticities calculated over the 10-year period, and are not equivalent to "marginal" (behavioural) elasticities.
24. This does not imply that such new construction is not economically desirable, just that public finance policy and constraints may not allow the "wealth/output-maximising" level of road new construction to occur. Several of the political/finance factors that might be limiting include: degree of political stability, degree of public corruption, lack of public revenue raising capacity, tax avoidance and high inflation.
25. This would not generally be practical along with the public finance factor.
26. The exception is the North American privately owned freight railways.
27. This does not imply that such new construction is not economically desirable, just that public finance policy and constraints may not allow the "wealth/output-maximising" level of road new construction to occur.
28. Bleijenberg (2002), p. 4.
29. The discussion at the Second Steering Group Meeting (12 December 2005) of the OECD Futures Project: Global Infrastructure Needs identified the importance of relating "needs" and "costs" to "benefits" – so as to highlight that such requirements were economically justified (*i.e.* as cost-beneficial), rather than being engineering/political "wish lists".
30. This is a finding of Canning-Pedroni (1999).
31. Conservative, as benefits are expected to exceed costs (by an unknown amount), on the maintained assumption that these relationships reflect some amount of public capital constrained behaviour.
32. This compares to annual GDP growth of 2.9% (2004-30), implying an arc-elasticity of vkm-to-GDP of 1.00. Note that this was not assumed, but resulted from the combination of model assumptions.
33. From 290 M vkm per billion USD-GDP (2000) to 323 M vkm per billion USD-GDP (2030), a cumulative growth of 11%.
34. From 3 560 M vkm per billion USD-road asset value (2000) to 5 280 M vkm per billion USD-road asset value (2030), a cumulative growth of 48%.
35. Lakshmanan-Anderson (2002), p. 10.
36. Lakshmanan-Anderson (2002), p. 17.
37. OECD (2004), p. 58.
38. Hilferink (2003), p. 80, specifically dealing with the EU.
39. Reynaud (2004), p. 10.

40. Population ageing will not be operative over the 2000-30 period in most Big 5 and developing countries.

41. Tardieu (2005), Slide 37 which shows EU growth of 1.5% for tonnes, 2.7% for tonne-km, 3.4% for vehicle-km, and 4-5% for corridor-specific vehicle-km.

42. Reynaud (2004), p. 8.

43. UK-RAE (2005), p. 33.

44. Specific examples include: US national highways (1950s security); Canada railways (1880s land settlement, response to annexation threat); China-Tibet political linkage (ongoing); Brazil-Amazon resource development (1970s-ongoing).

45. See Ackroyd (2001), for detail on London development over the millennia.

46. For example, vehicle ownership, road/rail network lengths, and road/rail capital value per route-km are all estimated at the national level for countries for which data are available from the primary sources (*e.g.* CIA Factbook, IRF Road Statistics). These national data reflect base-year (roughly 2000) experience resulting from variation in spatial distribution, population density, topographical features, demographics, etc.

47. The concept that taxes represent a "price" for public services is well accepted in *theory* in the public economics literature. As more public services have become "commercialised" with explicit user charges, there has been growing acceptance of this in *practice*. However, generalised road access has not been one of the public services for which this principle has been applied in practice – leading to much unproductive debate about whether road users already "pay" their fair share for road access through general taxes which go to general government revenues and are not available specifically for road (and other land transport) infrastructure operation, maintenance, or investment.

48. Andrieu (2005), Figure 3, citing Beecher (2003).

49. *Globe and Mail* (2 November 2005) reports that China seeks private (likely minority) involvement in major rail infrastructure plans.

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ANNEX 4.A1

Acronyms

Term/acronym	Definition
Ξ	Elasticity
%Δ	Percentage Change
adv	Annual Distance Driven per Vehicle
CIA	Central Intelligence Agency (US)
DoT/MoT	Department (Ministry) of Transport
ECMT	European Conference of Ministers of Transport
EU	European Union
GDP	Gross Domestic Product
GDPpc	Gross Domestic Product per capita
GHG	Green-House Gases
HIC	High-Income Countries
HSR	High-Speed Rail
IRF	International Road Federation
km	Kilometres
L/MIC	Low- and Medium-Income Countries
NC	New Construction
NIMBY	Not In My Back Yard
OECD	Organisation for Economic Co-operation and Development
PPP	Public-Private Partnerships
PRCS	Paved-Road Capital Stock
RTCS	Rail-Track Capital Stock
TEN-T	Trans-European Network for Transport
UK	United Kingdom
UN	United Nations
US	United States
vhp	Vehicles per Hundred (100) Population
vkm	Vehicle Kilometres (Distance Driven)
WB	World Bank

ANNEX 4.A2

Data Sources and Model

A. Socioeconomic drivers

Population: Base-level population (2004) is from US-CIA (2005); while growth rates for 2000-30 are from the United Nations (2004) – medium scenario.

Output: Base-level GDP and GDPpc (2004) are from US-CIA (2005); while growth rates for 2000-30 are from the World Bank (2005), with the latter adjusted so that:

- GDP growth rates for the period 2000-06 were used for 2004-10; and for the period 2006-15 were used for 2010-20 and 2020-30;
- some adjustments were made to specific (disaggregated) regions to respect regional-summary growth rates; and
- GDPpc growth rates for the period 2000-30 were calculated to be consistent with UN-population forecasts.

B. Road variables

Vehicles: Base-level road vehicle stock (roughly 2000) is from IRF (2003); with "missing values" estimated from vehicles per 100 population (vhp), which were themselves estimated on the basis of GDPpc. Regional results for vhp were then calculated.

The estimates of vhp for individual countries exploited a simplified step-function of the (basically logarithmic) relationship between vhp and GDPpc, so that:

vhp = fcn (GDPpc) such that:

- (for GDPpc < USD 5 000): = 1.00 * (GDPpc/1 000)
- (for USD 5 000 < GDPpc < USD 10 000): = [3 – (10 000/GDPpc) * (GDPpc/1 000)
- (for USD 10 000 < GDPpc): = 2.00 * (GDPpc/1 000)

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The growth rate of vhp for 2000-30 exploited the above relationship and the forecast growth in GDPpc (derived from WB and UN forecasts for GDP and population), with specific adjustment factors for each region to allow for "convergence" to the expected vhp by 2030 for developing countries, while dampening (*i.e.* capping) the higher vhp result for industrialised countries.

Distance driven (vkm): Base-level distance driven (roughly 2000) is from IRF (2003) – based on vehicle stock and annual distance per vehicle (adv); with "missing values" assumed based on known "matched countries" or otherwise "guestimated". Regional results for distance driven (vkm) and for annual distance per vehicle (adv) were then calculated.

The future levels of adv for 2010, 2020 and 2030 were based on assumption of "convergence" towards an adv = 15 000 long-term point, such that among industrialised countries/regions there would be cross-country convergence around the current mean values of adv, and there would be long-term declines in adv for (almost all) Big 5 and developing countries as the rate of vehicle ownership grew and high-adv buses were (relatively) displaced by lower-adv private vehicles.

Paved highways (pkm): Base-level paved highways (roughly 2000) are from US-CIA (2005) and IRF (2003).

Paved road capital stock (USD billion): Base-level paved-road capital stock (PRCS) is estimated based on paved highways (pkm) and an estimate of asset value per pkm. The latter was based on two empirical observations. The first, (Heggie-Vickers, 1998) is that the mean asset value per pkm for 13 developing countries was about USD 0.2M. The second, (Munnell, 1993) was that the road asset value for the United States was about 13% of GDP in 1990 – which with these base-level values implies a mean asset value per pkm of about USD 0.4 M. This suggests that the "quality" of paved-roads also increases as GDPpc rises. In order to allow for some transition between these levels, it is assumed in calculating base-level PRCS that:

Asset value per pkm = fcn (GDPpc) such that:

- (for GDPpc < USD 5 000): = 0.2
- (for USD 5 000 < GDPpc < USD 10 000): = 0.2 + [((GDPpc – 5 000)/1000) * 0.04]
- (for USD 10 000 < GDPpc): = 0.4

The ratio of PRCS to GDP is of considerable importance, as evidence (Munnell, 1993, etc.) indicates that this is falling over time for high-income industrialised countries, but likely needs to rise for developing countries (Canning-Padroni, 1999) as the evidence indicates a positive elasticity of PRCS with respect to GDPpc. Effectively, three relationships are exploited in the estimation of future levels of PRCS.

- Step 1: a rising level of PCRS as GDPpc rises;

- Step 2: a rising quality of asset value per pkm as GDPpc rises (as above); and
- Step 3: long-term convergence of the ratio of PRCS-GDP.

Initially, empirical estimates were made using the first two steps. This generally resulted in the downward drift over time of the ratio of PRCS-GDP in industrialised countries, but it did not produce any noticeably upward change in the ratio of PRCS-GDP for Big 5 and developing countries. The reason for this (*ex post* rationalisation) was that the elasticity effect (Step 1) assumes implicitly that the base level of PRCS is "optimal" to some degree – whereas in most cases it is significantly sub-optimal (see Canning-Pedroni, 1999; and casual empiricism). Therefore, there is a need to some closing of the "infrastructure gap" by raising the ratio of PRCS-GDP over time for Big 5 and developing countries.

Step 1: Application of elasticity of PRCS wrt GDP

It is assumed, based on a review of estimates and the 2-tier approach of Fay-Yepes (2003) that the elasticity of PRCS-GDP (ξ_{pr}) is:

- ξ_{pr} = fcn (GDPpc) such that:
- (for GDPpc < USD 5 000): = 0.15
- (for USD 5 000 < GDPpc < USD 10 000): = 0.15 + [((GDPpc – 5 000)/1000) * 0.02]
- (for USD 10 000 < GDPpc): = 0.25

The forecast PRCS is then the straightforward application of the %Δ-PCRS = ξ_{pr} * %Δ-GDPpc; the latter coming from the author's GDP and population growth forecasts – where:

$$PRCS_t^1 = PRCS_{t-10} * [(1 + \%\Delta\text{-}PCRS)^{\wedge}10\,] \text{ (for t = 2010, 2020, 2030)}$$

Step 2: Application of rising asset value per pkm as GDPpc rise:

The Step-1 estimate of $PRCS_t^1$ is transformed into units of pkm based on the initial asset value per pkm, and then this amount is multiplied by the current asset value per pkm (which may have risen as GDPpc rises) – which was estimated using the step-function shown above for PRCS.

$$PRCS_t^2 = PRCS_t^1 * \text{Factor (depending on step-function)}$$

It should be noted that this has a relatively minor effect for countries whose GDPpc rises from USD 5 000 to USD 10 000 only.

Step 3: Application of convergence in ratio of PRCS-GDP:

Among the industrialised countries/regions for which this model is applied, the average ratio of PRCS-GDP is 0.127 (in 2000) – with a range from a low of 0.039 (Germany) to a high of 0.276 (Non-OECD Europe and Central Asia). As already noted, there is a general downward trend for most industrialised countries over time (*e.g.* US, EU-12 as a whole), and there is evidence and widespread consensus that the current level of paved-road infrastructure in most Big 5 and developing countries is too low (*i.e.* sub-optimal). Among combined Big 5 and developing countries/regions, the average ratio of PRCS-GDP is 0.046 (in 2000) – with a range from a low of 0.012 (China) to a high of 0.138 (developing Europe and Central Asia).[1]

It is therefore assumed that a lower-bound ratio of PRCS-GDP is about 0.050 (*i.e.* although the possible long-run "convergence point" may be somewhat higher). Countries whose ratio of PRCS-GDP fall below 0.050 will face pressure (or desire to) close the gap between their current level of PRCS-GDP and this "lower-bound". However, the elimination of this "infrastructure gap" is allowed to extend over the entire 30-year period (or more for most countries/regions). The "makeup factors" are determined as:

- *For the period 2000-10:* for countries/regions with an infrastructure gap, 33% of the PRCS-gap which existed in 2000 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period;
- *For the period 2010-20:* for countries/regions with an infrastructure gap, 66% of the PRCS-gap which existed in 2010 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period; and
- *For the period 2020-30:* for countries/regions with an infrastructure gap, 100% of the PRCS-gap which existed in 2020 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period.

Because it is assumed that the 10-year lagged "infrastructure gap" is closed, none of the Big 5 or industrialised countries/regions with an "infrastructure gap" in 2000 actually reaches the 0.050 ratio of PRCS-GDP by 2030. In fact, even with the "convergence" approach (in Step 3), the average ratio of PRCS-GDP among combined Big 5 and developing countries/regions *actually falls* from 0.046 (in 2000) to 0.038 (in 2030). Clearly, a very-long term convergence process has been allowed for.

$PRCS_t^3 = PRCS_t^2$ + "Makeup Factor" (as described above)

The impact of "make-up" factors is most significant for China, Brazil, and developing East Asia-Pacific.

New construction (USD billion): Base-level annual new construction (NC) figures (assumed to be for paved roads) are from IRF (2003), with "missing values" assumed based on known "matched countries" or otherwise "guestimated".[2]

The future levels of new construction for 2010, 2020 and 2030 were determined from the forecast values of PCRS, based on two components:

- the annualised value from growth in paved road asset value (D-PCRS) over the decade; and
- replacement capital needed to maintain the existing value of PCRS from 10 years ago.

Component 1: Growth in PRCS

Annual new construction is simply 1/10th the paved road asset value growth over the decade.

$NC_t^1 = (PRCS_t - PRCS_{t-10})/10$ (for t = 2010, 2020, 2030)

Component 2: Replacement capital due to PRCS depreciation

In capital costing and accounting for roads, the economic useful life of the road asset is assumed to be about 30 years. This means that each year (in a steady state of no asset growth), about 1/30th of the asset value must be replaced per year. As there is new construction but no desire to construct a complicated depreciation/capital asset model, the 1/30th depreciation factor is applied to the PRCS lagged 10 years.

$NC_t^2 = (PRCS_{t-10})/30$ (for t = 2010, 2020, 2030)

The total annual value of new construction is the sum of these two components:

$NC_t = NC_t^1 + NC_t^2$

$= [(PRCS_t - PRCS_{t-10})/10] + [(PRCS_{t-10})/30]$

$= [(PRCS_t - (2/3 * PRCS_{t-10}))/10]$ (for t = 2010, 2020, 2030)

It should be noted that the replacement capital is much the greater of the two, accounting for 81% of NC in 2010, falling to 72% in 2030 (*i.e.* is 3-4 times as large as the new construction which results in net addition to the PRCS asset value).

C. Rail variables

Rail-track (rkm): Base-level railway lengths (roughly 2000) are from US-CIA (2005).

Rail-track Capital Stock (USD billion): Base-level rail-track capital stock (RTCS) is estimated based on rail-track length (rkm) and an estimate of asset value per rkm. The latter was based on many discrete railway sources, and varied from a high of USD 3.33M/rkm in Japan, to an assumed low of USD 0.25M/rkm in developing countries – with an observed low of USD 0.31M/rkm for Canada.[3]

The same "model" was applied to rail as in road – with various parameters (principally dealing with asset value per rkm) both to allow for rising quality of infrastructure over time, and (more importantly) to boost the rail new construction levels to be consistent with published spending intentions for China railways,[4] and for OECD (TEN-T High-Speed Rail).[5]

Rail-track new construction (USD billion): Base-level rail-track new construction (RTNC) is estimated based on a proportion of RTCS. These

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proportions were estimated from the same discrete railway sources, and varied from a high of 8.9% in Italy to an assumed low of 2.5% in developing countries – with an observed low of 4.0% in Japan.[6]

The future levels of new construction for 2010, 2020 and 2030 were determined from the forecast values of RTRS, based on the same two components and methodology as for roads.

Notes

1. The high (relative) ratios of PRCS-GDP for the industrialised and developing regions of Europe and Central Asia are believed (hypothesised) to be a result of communist central planning practises – which were not shared by China and North Korea.
2. The estimation process for base-year new construction is somewhat involved, and has no impact on forecast estimates. It is used solely as a point of comparison. In general terms, the expected level of maintenance spending on paved roads was estimated using a known (or assumed) value per pkm (ranging from USD 2 000-10 000, depending on GDPpc) times the number of pkm. The percentage of road spending devoted to new construction (% new) was then either known or assumed (depending on growth rate and GDPpc, with a range from 20% to 60%).
3. Data were primarily for individual railways in particular countries, using Annual Report values for rkm and net asset value for track-buildings-facilities (excluding rolling stock). Railways included: Queensland Rail (Australia), BNSF (United States), JR-East (Japan), Network Rail (United Kingdom), FS/RFI (Italy), CN/CP (Canada), DB (Germany).
4. *Globe and Mail* (2 November 2005), "Chinese railways plan to sell shares" (AP story), which reports planned spending of USD 61 billion over 2006-10, which in this model has been treated as plans for USD 10 billion/year over a 20-year period (2000-20), with roughly half in each of the two 10-year periods.
5. EU (2003), Table 3, p. 390 shows TEN-T priority projects involving dedicated rail-projects worth EUR 130 billion over 20 years, which has been taken to mean about USD 7.7 billion/year. However, there are rail infrastructure investments outside of TEN-T projects, and data for Italy (FS/RFI) suggest that HSR may be only 50% of spending – so it is effectively assumed that European OECD spending will be about USD 15 billion/year over the entire 2000-30 period.
6. The low investment rate for Japan should be seen more as a reflection of the very high rkm values for Japan TRCS than as a sign of underinvestment.

ANNEX 4.A3

Economic Growth Assumptions

Global economic outlook Growth assumptions	A	B	Based on World Bank C	 D	 E	F	G
	2004 GDP value (USD-B)	2004 GDP per capita (USD)	2000-10 GDP growth (%)	2010-20 GDP growth (%)	2020-30 GDP growth (%)	2030 GDP per capita (USD)	2030 GDP value (USD-B)
REGIONS OF THE WORLD							
1. High–income/industrialised	***35 023***	***24 964***	***2.28***	***2.14***	***2.16***	***38 631***	***61 325***
***a)* G-7**	***24 008***	***33 457***	***2.21***	***2.09***	***2.12***	***52 489***	***41 551***
United States	11 750	40 100	2.69	2.55	2.55	62 988	22 799
Japan	3 745	29 400	1.75	1.61	1.61	46 751	5 720
Germany	2 362	28 700	1.48	1.34	1.34	41 378	3 369
United Kingdom	1 782	29 600	1.75	1.61	1.61	41 379	2 722
France	1 737	28 700	1.81	1.67	1.67	41 959	2 697
Italy	1 609	27 700	1.52	1.38	1.38	41 658	2 317
Canada	1 023	31 500	2.57	2.43	2.43	47 932	1 927
***b)* Other–OECD**	***7 648***	***16 998***	***2.40***	***2.20***	***2.20***	***26 736***	***13 629***
Europe and Central Asia	5 009	18 484	2.30	2.10	2.10	29 514	8 703
East Asia and Pacific	1 633	22 451	2.65	2.20	2.28	37 044	2 975
North America (Mexico)	1 006	9 600	2.50	2.70	2.50	14 488	1 950
OECD Industrialised	***31 656***	***27 114***	***2.26***	***2.12***	***2.14***	***42 401***	***55 180***
***c)* Non–OECD**	***3 367***	***14 302***	***2.49***	***2.29***	***2.29***	***21 480***	***6 145***
East Asia and Pacific	1 186	19 905	2.69	2.49	2.29	28 917	2 232
Europe and Central Asia	236	12 222	1.79	1.09	1.49	20 118	339
Latin America and Caribbean	851	12 223	2.69	2.19	2.29	18 640	1 555
Middle East and North Africa	574	14 406	2.69	3.49	2.89	19 138	1 262
South Asia	16	12 764	2.29	2.09	2.29	19 760	28
Sub-Sahara Africa	507	11 015	1.79	0.99	1.69	17 822	736

Global economic outlook Growth assumptions	A	B	Based on World Bank			F	G
			C	D	E		
	2004 GDP value (USD-B)	2004 GDP per capita (USD)	2000-10 GDP growth (%)	2010-20 GDP growth (%)	2020-30 GDP growth (%)	2030 GDP per capita (USD)	2030 GDP value (USD-B)
2. Big 5	***14 308***	***4 837***	***4.64***	***3.99***	***4.07***	***10 677***	***41 393***
China	7 262	5 600	5.44	4.83	4.83	15 879	25 631
India	3 319	3 100	4.17	3.26	3.26	5 117	8 058
Brazil	1 492	8 100	3.78	2.92	2.92	11 850	3 315
Russia	1 408	9 800	3.44	2.41	2.41	22 251	2 777
Indonesia	827	3 500	2.74	2.56	2.56	5 205	1 613
3. Developing	***6 252***	***3 001***	***3.69***	***2.95***	***2.99***	***4 990***	***13 957***
East Asia and Pacific	1 283	4 445	4.49	3.74	3.74	10 314	3 478
Europe and Central Asia	971	4 005	5.07	3.17	3.17	8 299	2 439
Latin America and Caribbean	954	4 878	2.45	1.97	1.97	6 757	1 629
Middle East and North Africa	1 642	3 521	3.05	2.47	2.47	4 895	3 201
South Asia	780	2 104	4.12	3.43	3.43	3 977	1 951
Sub-Sahara Africa	622	1 197	2.73	2.75	2.75	1 606	1 259
WORLD	***55 583***	***8 625***	***3.07***	***2.78***	***2.89***	***14 093***	***116 675***

ANNEX 4.A4

Road Vehicles and Ownership Forecast

Global road outlook Vehicles and ownership	A 2000 Total road vehicles (M)	B 2000 Annual distance (Bkm)	C 2000 Road vehicles per 100 population	D 2010 Road vehicles per 100 population	E 2020 Road vehicles per 100 population	F 2030 Road vehicles per 100 population	G 2030 Annual distance (Bkm)	H 2030 Total road vehicles (M)
REGIONS OF THE WORLD								
1. High–income/industrialised	***652.1***	***11 240***	***46.5***	***50.4***	***58.0***	***67.3***	***18 769***	***1 067.6***
***a)* G-7**	***466.0***	***7 673***	***64.9***	***69.0***	***76.4***	***84.6***	***11 455***	***670.0***
United States	230.4	4 391	77.9	82.5	90.8	100.2	6 875	362.5
Japan	74.0	786	58.1	61.4	67.7	74.7	1 089	91.4
Germany	46.8	648	56.8	60.2	66.3	73.1	899	59.6
United Kingdom	26.0	518	42.9	45.3	49.9	55.0	705	36.2
France	35.4	527	58.3	61.7	68.0	75.0	753	48.2
Italy	35.2	525	60.7	64.3	70.8	78.2	691	43.5
Canada	18.3	278	55.7	58.7	64.5	71.2	443	28.6
***b)* Other–OECD**	***141.4***	***2 649***	***31.4***	***35.1***	***43.0***	***53.5***	***5 029***	***272.8***
Europe and Central Asia	94.3	1 705	34.8	38.7	47.5	59.1	3 154	174.2
East Asia and Pacific	28.7	587	39.5	45.7	57.5	74.0	1 136	59.5
North America (Mexico)	18.5	358	17.4	19.4	23.7	29.0	739	39.1
OECD Industrialised	***607.5***	***10 323***	***52.0***	***55.8***	***63.3***	***72.4***	***16 484***	***942.8***
***c)* Non–OECD**	***44.7***	***917***	***19.0***	***24.1***	***32.6***	***43.6***	***2 285***	***124.8***
East Asia and Pacific	13.5	235	22.6	30.1	42.5	57.8	730	44.6
Europe and Central Asia	7.1	82	36.9	40.7	45.2	51.7	116	8.7
Latin America and Caribbean	10.9	270	15.7	20.1	27.3	37.2	608	31.0
Middle East and North Africa	6.3	144	15.9	20.8	29.2	38.3	490	25.2
South Asia	0.1	2	11.5	15.6	24.6	39.5	8	0.6
Sub-Sahara Africa	6.7	184	14.5	18.9	25.2	35.6	332	14.7

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	A	B	C	D	E	F	G	H
Global road outlook Vehicles and ownership	2000 Total road vehicles (M)	2000 Annual distance (Bkm)	2000 Road vehicles per 100 population	2010 Road vehicles per 100 population	2020 Road vehicles per 100 population	2030 Road vehicles per 100 population	2030 Annual distance (Bkm)	2030 Total road vehicles (M)
2. Big 5	***85.1***	***2 322***	***2.9***	***4.2***	***8.8***	***14.6***	***13 677***	***566.8***
China	16.5	880	1.3	2.9	10.6	21.3	8 595	343.7
India	9.3	322	0.9	1.7	3.7	5.3	2 470	84.0
Brazil	29.0	518	15.6	17.6	20.9	23.7	1 213	66.2
Russia	25.4	489	17.7	21.6	30.8	44.4	1 012	55.5
Indonesia	5.0	112	2.1	2.6	3.8	5.6	388	17.4
3. Developing	***103.2***	***2 517***	***5.0***	***5.4***	***6.7***	***8.3***	***5 186***	***231.9***
East Asia and Pacific	22.4	499	7.8	9.2	14.2	20.6	1 343	69.6
Europe and Central Asia	22.7	622	9.4	10.0	11.1	14.9	1 090	43.8
Latin America and Caribbean	11.3	271	5.8	6.5	8.1	10.3	573	24.8
Middle East and North Africa	30.5	683	6.5	6.9	7.7	8.5	1 238	55.4
South Asia	2.7	65	0.7	1.0	2.2	2.4	278	11.8
Sub-Sahara Africa	13.5	377	2.8	2.8	3.1	3.4	664	26.6
WORLD	***840.4***	***16 079***	***13.1***	***14.4***	***18.0***	***22.5***	***37 632***	***1 866.3***

ANNEX 4.A5

Road Use Forecast

Global economic outlook Road use	A 2000 Road use-economy density (Mvkm per USD-B)	B 2000 Annual distance per vehicles (km)	C 2000 Annual distance (Bvkm)	D 2010 Annual distance (Bvkm)	E 2020 Annual distance (Bvkm)	F 2030 Annual distance (Bvkm)	G 2030 Annual distance per vehicles (km)	H 2030 Road use-economy density (Mvkm per USD-B)
REGIONS OF THE WORLD								
1. High–income/industrialised	***321***	***17 236***	***11 240***	***12 763***	***15 431***	***18 769***	***17 580***	***306***
***a)* G-7**	***320***	***16 465***	***7 673***	***8 457***	***9 756***	***11 455***	***17 096***	***276***
United States	374	19 056	4 391	4 873	5 720	6 875	18 963	302
Japan	210	10 625	786	865	965	1 089	11 911	190
Germany	274	13 854	648	712	801	899	15 097	267
United Kingdom	291	19 960	518	554	624	705	19 481	259
France	303	14 909	527	579	657	753	15 612	279
Italy	326	14 902	525	566	623	691	15 888	298
Canada	271	15 198	278	307	365	443	15 484	230
***b)* Other–OECD**	***346***	***18 736***	***2 649***	***3 101***	***3 978***	***5 029***	***18 437***	***369***
Europe and Central Asia	340	18 082	1 705	1 978	2 518	3 154	18 104	362
East Asia and Pacific	360	20 488	587	695	891	1 136	19 103	382
North America (Mexico)	356	19 351	358	428	569	739	18 904	379
OECD Industrialised	***326***	***16 994***	***10 323***	***11 558***	***13 734***	***16 484***	***17 484***	***299***
***c)* Non–OECD**	***272***	***20 529***	***917***	***1 205***	***1 697***	***2 285***	***18 304***	***372***
East Asia and Pacific	198	17 410	235	334	510	730	16 379	327
Europe and Central Asia	346	11 462	82	94	104	116	13 269	341
Latin America and Caribbean	318	24 719	270	345	476	608	19 585	391
Middle East and North Africa	251	22 765	144	204	333	490	19 417	389
South Asia	148	16 520	2	3	5	8	15 125	302
Sub-Sahara Africa	363	27 614	184	224	269	332	22 634	452

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	A	B	C	D	E	F	G	H
Global economic outlook Road use	2000 Road use-economy density (Mvkm per USD-B)	2000 Annual distance per vehicles (km)	2000 Annual distance (Bvkm)	2010 Annual distance (Bvkm)	2020 Annual distance (Bvkm)	2030 Annual distance (Bvkm)	2030 Annual distance per vehicles (km)	2030 Road use-economy density (Mvkm per USD-B)
2. Big 5	***162***	***27 275***	***2 322***	***3 808***	***8 226***	***13 677***	***24 131***	***330***
China	121	53 393	880	1 722	4 709	8 595	25 004	335
India	97	34 691	322	687	1 560	2 470	29 397	307
Brazil	348	17 894	518	673	942	1 213	18 321	366
Russia	347	19 262	489	576	766	1 012	18 248	364
Indonesia	135	22 444	112	150	249	388	22 285	240
3. Developing	***403***	***24 210***	***2 517***	***2 966***	***3 974***	***5 186***	***22 363***	***372***
East Asia and Pacific	389	22 227	499	621	936	1 343	19 313	386
Europe and Central Asia	641	27 368	622	704	843	1 090	24 885	447
Latin America and Caribbean	284	24 089	271	327	439	573	23 152	352
Middle East and North Africa	416	22 411	683	796	1 002	1 238	22 324	387
South Asia	83	23 684	65	94	231	278	23 606	143
Sub-Sahara Africa	606	26 334	377	424	523	664	24 985	527
WORLD	***289***	***19 114***	***16 079***	***19 537***	***27 631***	***37 632***	***20 164***	***323***

ANNEX 4.A6

Road Construction Forecast

	A	B	C	D	E	F	G	H
Global Road Construction Outlook comparison of results	2000 Asset value (USD-B)	2000 PRCS % of GDP	2000 New construction (USD-B)	2000-10 Annual "new construction" (USD-B)	2010-20 Annual "new construction" (USD-B)	2020-30 Annual "new construction" (USD-B)	2030 PRCS % of GDP	2030 Asset value (USD-B)
REGIONS OF THE WORLD								
1. High-income/industrialised	***4 436.5***	***12.7***	***100.4***	***168.0***	***176.6***	***191.2***	***8.4***	***5 150.2***
***a)* G-7**	***3 030.9***	***12.6***	***81.5***	***113.6***	***119.2***	***126.4***	***8.3***	***3 462.0***
United States	1 672.0	14.2	52.6	62.4	65.6	69.3	8.3	1 902.8
Japan	361.3	9.6	6.1	13.5	14.2	15.1	7.2	412.8
Germany	92.3	3.9	2.3	4.3	4.6	5.8	4.0	134.6
United Kingdom	157.2	8.8	4.3	5.8	6.0	6.1	6.4	173.3
France	357.2	20.6	8.9	13.2	13.7	14.3	14.8	398.5
Italy	191.9	11.9	2.9	7.1	7.4	7.8	9.3	215.7
Canada	198.9	19.4	4.5	7.4	7.7	8.1	11.6	224.3
***b)* Other–OECD**	***1 194.3***	***15.6***	***17.2***	***45.8***	***47.9***	***51.7***	***10.2***	***1 393.4***
Europe and Central Asia	976.8	19.5	13.7	37.0	38.6	40.7	12.9	1 118.6
East Asia and Pacific	176.0	10.8	2.3	6.8	7.0	7.5	6.8	203.8
North America (Mexico)	41.5	4.1	1.2	2.0	2.2	3.5	3.6	71.0
OECD Industrialised	***4 225.2***	***13.3***	***98.7***	***159.4***	***167.1***	***178.1***	***8.8***	***4 855.4***
***c)* Non–OECD**	***211.3***	***6.3***	***1.7***	***8.6***	***9.5***	***13.1***	***4.8***	***294.8***
East Asia and Pacific	38.9	3.3	0.5	2.1	2.5	3.8	3.4	75.7
Europe and Central Asia	65.0	27.6	0.4	2.5	2.6	2.8	22.2	75.3
Latin America and Caribbean	50.6	6.0	0.3	1.9	2.0	2.8	4.1	64.4
Middle East and North Africa	30.8	5.4	0.4	1.1	1.3	2.4	3.7	46.7
South Asia	0.8	5.0	0.0	0.0	0.0	0.0	3.9	1.1
Sub-Sahara Africa	25.3	5.0	0.2	1.0	1.1	1.3	4.3	31.7

	A	B	C	D	E	F	G	H
Global Road Construction Outlook comparison of results	2000 Asset value (USD-B)	2000 PRCS % of GDP	2000 New construction (USD-B)	2000-10 Annual "new construction" (USD-B)	2010-20 Annual "new construction" (USD-B)	2020-30 Annual "new construction" (USD-B)	2030 PRCS % of GDP	2030 Asset value (USD-B)
2. Big 5	***582.7***	***4.1***	***9.3***	***36.6***	***46.6***	***64.7***	***3.1***	***1 293.2***
China	88.6	1.2	2.4	15.2	23.8	37.8	2.5	630.6
India	289.7	8.7	6.2	10.6	10.8	11.9	4.0	324.1
Brazil	30.7	2.1	0.3	2.9	3.7	5.0	2.9	96.9
Russia	142.0	10.1	0.3	6.5	6.5	7.1	6.7	185.4
Indonesia	31.7	3.8	0.2	1.4	1.8	2.8	3.5	56.3
3. Developing	***353.2***	***5.7***	***5.0***	***15.7***	***22.0***	***36.4***	***4.9***	***685.2***
East Asia and Pacific	28.1	2.2	0.4	2.6	4.3	6.8	3.3	116.5
Europe and Central Asia	133.8	13.8	2.0	5.5	9.4	13.4	10.7	260.4
Latin America and Caribbean	33.3	3.5	0.9	1.9	1.9	3.9	4.3	69.4
Middle East and North Africa	81.4	5.0	0.4	2.9	3.4	6.3	3.8	122.3
South Asia	37.5	4.8	1.2	1.5	1.7	3.9	3.5	67.8
Sub-Sahara Africa	39.2	6.3	0.1	1.4	1.4	2.2	3.9	48.8
WORLD	***5 372.5***	***9.7***	***114.8***	***220.3***	***245.2***	***292.3***	***6.1***	***7 128.6***

ANNEX 4.A7

Rail Construction Forecast

	A	B	C	D	E	F	G	H
Global Rail Construction Outlook comparison of results	2000 Asset value (USD-B)	2000 RTCS % of GDP	2000 New construction (USD-B)	2000-10 Annual "new construction" (USD-B)	2010-20 Annual "new construction" (USD-B)	2020-30 Annual "new construction" (USD-B)	2030 RTCS % of GDP	2030 Asset value (USD-B)
REGIONS OF THE WORLD								
1. High–income/ industrialised	***468.5***	***1.3***	***27.7***	***33.3***	***36.8***	***36.8***	***1.5***	***900.8***
***a)* G-7**	***329.7***	***1.4***	***21.3***	***20.8***	***23.3***	***23.8***	***1.4***	***583.2***
United States	93.4	0.8	5.6	5.2	6.3	8.8	0.8	180.8
Japan	78.5	2.1	3.1	3.2	3.4	3.7	1.7	97.8
Germany	43.8	1.9	3.6	4.0	4.5	3.5	2.8	95.9
United Kingdom	24.8	1.4	2.0	1.8	2.0	1.6	1.6	44.9
France	28.0	1.6	2.1	2.6	2.9	2.3	2.3	61.6
Italy	46.3	2.9	4.1	2.7	3.0	2.6	3.1	72.0
Canada	14.9	1.5	0.6	1.3	1.1	1.3	1.6	30.2
***b)* Other–OECD**	***111.4***	***1.5***	***5.6***	***10.3***	***11.1***	***9.6***	***1.8***	***248.8***
Europe and Central Asia	84.0	1.7	4.4	8.2	9.2	7.2	2.2	194.1
East Asia and Pacific	22.0	1.3	1.0	1.5	1.4	1.7	1.3	39.4
North America (Mexico)	5.4	0.5	0.2	0.6	0.4	0.8	0.8	15.3
OECD Industrialised	***441.1***	***1.4***	***26.9***	***31.1***	***34.3***	***33.4***	***1.5***	***832.0***
***c)* Non–OECD**	***27.4***	***0.8***	***0.8***	***2.3***	***2.5***	***3.4***	***1.1***	***68.8***
East Asia and Pacific	1.6	0.1	0.0	0.4	0.4	0.7	0.6	12.5
Europe and Central Asia	5.8	2.4	0.2	0.3	0.3	0.4	2.6	8.7
Latin America and Caribbean	10.8	1.3	0.3	0.9	1.1	1.3	1.7	26.8
Middle East and North Africa	0.7	0.1	0.0	0.2	0.2	0.4	0.5	6.9
South Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Sahara Africa	8.6	1.7	0.2	0.5	0.5	0.6	1.9	13.8

	A	B	C	D	E	F	G	H
Global Rail Construction Outlook comparison of results	2000 Asset value (USD-B)	2000 RTCS % of GDP	2000 New construction (USD-B)	2000-10 Annual "new construction" (USD-B)	2010-20 Annual "new construction" (USD-B)	2020-30 Annual "new construction" (USD-B)	2030 RTCS % of GDP	2030 Asset value (USD-B)
2. Big 5	***100.3***	***0.7***	***4.4***	***12.2***	***13.3***	***15.0***	***0.8***	***322.3***
China	28.8	0.4	1.4	7.3	8.1	7.7	0.7	171.9
India	19.0	0.6	1.0	1.5	1.8	2.9	0.7	52.9
Brazil	7.4	0.5	0.2	1.0	0.7	1.3	0.7	24.3
Russia	43.6	3.1	1.7	2.1	2.3	2.6	2.3	64.1
Indonesia	1.6	0.2	0.0	0.3	0.3	0.5	0.6	9.0
3. Developing	***62.6***	***1.0***	***1.9***	***3.5***	***3.4***	***6.3***	***0.9***	***119.7***
East Asia and Pacific	3.5	0.3	0.1	0.5	0.6	1.1	0.5	18.3
Europe and Central Asia	30.5	3.1	1.1	1.3	1.4	1.6	1.6	39.8
Latin America and Caribbean	5.3	0.6	0.1	0.4	0.3	0.8	0.8	12.6
Middle East and North Africa	9.0	0.5	0.2	0.6	0.5	1.5	0.7	23.4
South Asia	4.1	0.5	0.1	0.3	0.2	0.9	0.7	13.0
Sub-Sahara Africa	10.3	1.6	0.3	0.4	0.4	0.5	1.0	12.6
WORLD	***631.4***	***1.1***	***34.0***	***49.0***	***53.5***	***58.1***	***1.2***	***1 342.8***

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Chapter 5

The Impacts of Change on the Long-term Future Demand for Water Sector Infrastructure

by

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1. Introduction

Background

Water is like no other commodity, excepting food, in that it is essential to human life. The greatest challenges facing us relate to the conditions in which we live, how we are nourished and sheltered. Water is a central issue in a world that is increasingly urbanised and has a rising population to feed and seemingly ever increasing risks.

The 20th century saw global population triple and the development of megacities. Water consumption rose, both in total amount needed and in per capita demand. Increasing pollution loads and abstractions have outstripped the assimilative capacity of ecosystems. Across the world, urbanisation has progressed through stages of ever denser habitation. Water service and infrastructure are meant to keep pace with these changes in developed countries: typically, there is an assumption that the services will follow the newest needs in terms of how people work and live. (For a fuller discussion see Juuti and Katko, 2005.) Ironically, in many of the countries, water is undervalued by the citizens who live in towns and cities because it is readily available from the tap. Once used, it is then flushed away down the toilet or the sink and is never seen or thought of again. Up to one-third of the water supplied to domestic properties is used for toilet flushing and a further significant proportion is used for purposes other than drinking; in some countries, including Australia, water used for domestic gardening can constitute more than 50% of domestic use. Worldwide, the demand for water for irrigation is now consuming some 75% of the total abstracted. In anticipation of this explosion in water use there was significant investment in the past in the provision and operation of water infrastructure, much of it in informal and low-technology groundwater pumping, some of which helps grow cheap crops exported from the developing countries to the developed world. Worryingly, much of this water use is unsustainable (New Scientist, 2006).

Consumption rates reflect availability and continuity of supply, relative wealth including size of property, and to some extent correlate with climate. WHO/UNICEF specifies that reasonable access to water means at least 20 litres per person per day (l/h/d), accessible within 1 km of that person's dwelling. However, this is a bare minimum; 50 l/h/d are required to ensure health and hygiene (Stephenson, 2001). Per capita consumption rates of more than 500 litres per day used to be common in the United States, but this has now declined to below 400 litres, depending on the state. In most European countries the

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consumption is between 100 and 200 l/h/d. In countries with only standpipe supplies, average per capita consumption rates are some 20-60 l/h/d. The question of what consumption rates are to be met and in what manner has a huge impact on the development of water resources and the nature of the services provided, as well as the financial and institutional implications for the country. Metering of domestic consumption is not applied globally even in the most developed countries, and evidence suggests that it may have only a limited effect on constraining long-term use. In the United States not all properties are metered; in the Netherlands and the United Kingdom some 20-30% are metered, with slightly more in Germany and Denmark and some 75% in Australia. In a survey of 27 major Asian cities with populations exceeding 1 million in 1996, the ADB found that 15 were fully metered, six had metering for less than 7% of the population, and virtually no metering existed in major Indian cities (Twort, Ratnayaka and Brandt, 2000).

While most of the developed world and the wealthiest customers in the developing countries do not pay the true economic costs of water services, the poorest have to purchase water from local carriers or bottles at up to 500 times the cost for their wealthy neighbours in the same country. Despite the availability of good-quality, continuous water supply from the tap in developed countries, there is an increasing demand for bottled water. This may be due to perceptions that it is of better quality, or for taste, fashion or convenience. Globally, the expenditure on bottled water has now reached some USD 100 billion per year and consumption is growing at a rate of 10% per annum (Gleick, 2004). The largest consumers are the United States, Mexico and China, with consumption in China growing the fastest in the period 1997-2002. Regionally, there has been considerable growth between 1997 and 2002 on all continents except in Africa. The amounts being spent on bottled water worldwide could pay for piped supplies to most of the world currently lacking these facilities, and the material and transport resource use and pollution from the packaging (mostly PET plastic) have major impacts (Ferrier, 2001). In some developing countries, manufacturers continue to over-abstract from aquifers to produce high-cost bottled water, compromising local supplies (Earth Policy Institute, 2006). Although the demand for bottled water could potentially reduce the need for global infrastructure for piped supplies this may be offset by the ensuing increases in energy demand, waste production and transport infrastructure needs. Increasing demand for bottled water may also influence decisions about the need to maintain the serviceability of existing water infrastructure assets. Ironically, the quality of bottled water is often dubious.

In addition to domestic supplies, water is also provided for:

- *Agriculture* – irrigation of crops, livestock, horticulture – very dependent on activities, local soils and sources and climate.

- *Trade and industry* – factories, shops and institutions such as hospitals; also for power generation and cooling. Consumption is very specific to the nature of the activities, but in a number of developed countries industrial demand has fallen due to: general decline in heavy industry in favour of service industries; better use of recycling and reuse/recovery of water locally; and better water accounting and auditing, reducing wastage and unnecessary use. Overall, demand in this sector is expected to rise by a small percentage worldwide from current levels of about 20% of global water use.
- *Public amenities* – parks, street washing, firefighting, flushing mains and sewers. This may be water provided free of charge (and unmeasured) where the water service provider (WSP) is a municipality. Firefighting is a major reason for ensuring that water main pressures are maintained, and for supplying high-rise buildings.
- *Losses* – in distribution systems, domestic leaks and dripping taps, where "unaccounted for" water is due to metering errors, unauthorised use and general unrecorded consumption (Alegre *et al.*, 2000). Unaccounted for water (including all losses) may comprise from 6% up to 55% of the total water supplied in areas with ageing mains and service pipes. Current leakage rates in London from the mains are up to 40%.

Only 2.3% of the earth's water is fresh, with two-thirds of that permanently frozen – although the percentage is declining due to global warming. Sources of water are mainly through direct precipitation, which is usually stored temporarily in natural areas or in man-made reservoirs that hold some 8 000 km^3. Some 8% of the annual freshwater renewable resource is used, with 26% of evapo-transpiration and 54% of runoff. Table 5.1 shows the regional availability of water resources compared with population distribution.

Table 5.1. **Regional availability of water resources**

% World's	North and Central America	South America	Europe	Africa	Asia	Australia and Oceania
Water	15	26	8	11	36	5
Population	8	6	13	13	60	<1
Ratio (%)	1.9	4.3	0.61	0.84	0.6	5

Some 2 million tonnes of waste is discharged daily, polluting some 12 000 km^3 of receiving waters. Climate change is expected to increase precipitation from latitudes 30° N and 30° S, with lower and more variable rainfall in tropical and subtropical regions. Extremes of weather will be more common, with more frequent disasters worldwide (UN, 2003). Levels of water supply and sanitation provision are given in Table 5.2 (WHO/UNICEF, 2005) and global water use in Table 5.7.

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Table 5.2. **Percentage of population served by water supply and sanitation services (2002)**

Infrastructure		World	Developed countries	Eurasia	Developing regions
Water supply	Urban	95	100	99	92
	Rural	72	94	82	70
	Total	83	98	93	79
Sanitation	Urban	81	100	92	73
	Rural	37	92	65	31
	Total	58	98	83	49

Table 5.2 illustrates those regions with less than 100% coverage of safe (or improved) systems of water supply and sanitation. It does not differentiate where service provision is local or provided via major and/or centralised infrastructure. The significance of this is illustrated in Table 5.3, which shows the proportions of urban dwellers with in-house facilities (Tipping, Adbm and Tibaijuka, 2005), and in Table 5.4, which shows the proportion of households connected to mains water and sewers (UN, 2003). Although having a flush toilet is not necessarily an appropriate measure in developing countries, Table 5.3 is indicative of the more local access to water and sanitation – information not explicit in Table 5.2.

Table 5.3. **Percentage of households with in-house access to safe drinking water and reliable sanitation**

Facility	North Africa		Sub-Saharan Africa		Southeast Asia		South, central, west Asia		Latin America	
Wealth	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor
Water on premises	75	92	31	46	36	50	59	74	59	74
Flush toilet	88	97	28	32	67	88	48	60	44	67

Table 5.4. **Proportion of households in major cities connected to mains water and sewers**

% with this facility	North America	Europe	Oceania	Latin America and Caribbean	Asia	Africa
House or yard connection for water	100	96	73	78	78	43
Sewer connection	96	92	14	34	45	17

Agriculture in general – and irrigated agriculture specifically – is by far the biggest consumer of water. Overall agriculture now accounts for about 75% of global water use (Gleick, 2004). Globally the number of irrigated hectares has almost doubled since 1960, with China, India and Pakistan accounting for almost all of that growth. The amount of irrigated area is falling per capita of the world's population, despite continuing to rise in absolute terms to 270 million hectares in 2001. The vast majority of this area is in Asia (190 million ha), with Europe showing a decline to 25 million ha in 2001 from a peak of 28 million in 1980. Elsewhere the irrigated area is stable. By volume, India, China, Pakistan and the United States together account for 75% of total agricultural usage. Data on agricultural usage are not reliable, as they are often severely underestimated for countries like India. If it is considered that the vast majority of this is under flood irrigation, which has an efficiency of at best 40%, then it is evident that a tremendous resource is not only going to waste but producing problems of aquifer exhaustion and soil salinisation. It also means that the economic productivity of this huge infrastructure that captures, stores and distributes water for irrigation is questionable.

Historic overview

Formal infrastructure systems for supplying water are almost as old as humanity. Between 16 000 and 10 000 years ago, agriculture developed and permanent settlements were established, requiring irrigation; hence, seasonal and other water shortages were experienced (Cosgrove, 2003). Reportedly the first major water infrastructure systems were constructed around 3000 BC by the Egyptians and the Sumerians. Around this time China was formally irrigating and by 2000 BC Egypt was maintaining large dams. In the period that followed, up to the birth of Christ, the Romans, Persians and others built major water supply and sanitation structures, some of which survive today. These advances were in response to urbanisation and the growth of towns and cities. Before major settlements, people followed the water, settling near rivers, lakes, and springs, and moving to others if these dried up because of climate variability. As technology evolved and settlements became larger, people moved the water to them. In the so-called Middle Ages, water was generally distributed by water carriers, or collected directly from wells, ponds and rivers. It was only in the mid-19th century that the connection between water and disease was established, highlighting the need for separation between sewage disposal and water supplies. Before then, sewage was disposed of via watercourses that provided the supply for others. This situation still prevails today in many less developed countries, even where water is abundant. The industrial revolution in the West and later in the East could not have occurred without adequate water or reliable and healthy workers. It is no coincidence that many of the countries nowadays with the most comprehensive water

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infrastructure are those that were at one time colonial powers. Revenue from colonisation provided the funds to construct many of the water infrastructure assets in the 19th century, most of which are still relied on today.

The establishment of modern water systems was originally largely based on private initiatives. These proved unreliable and from 1861 to 1901 the share of municipal water supplies in England, for example, grew from 40 to 90%. A similar trend was also evident in the United States. The growth of urban infrastructure was the most dynamic element of the British economy from the 1870s to the 1930s. Investments in public health, local transport, water, electricity and gas were by the early 1900s as much as one-quarter of all capital formation in Britain. In North America many urban water supply systems were built from 1830 to 1880; it proved more difficult to fund sewage systems (rather like many developing countries today). Ultimately the needs of society, businesses and industries hastened the birth of water works, making public works necessary. New York, Chicago and other cities started water acquisition and distribution with the help of private enterprise (Juuti and Katko, 2005).

Nowadays the less developed countries are faced with the need to industrialise rapidly to fulfil the expectations of their people, but often without the resources (governance, technical, financial and social capital) to provide the essential infrastructure to support this (Wolf, n.d.) and with an over-reliance on imported and sometimes inappropriate expertise and technology. This has often led to hasty and inappropriate exploitation of resources – including water – and neglect with regard to closing the water cycle, by concentrating on the provision of water supplies without accompanying sanitation. Dhaka provides an example of this, where the lack of sanitation means that water supplies are polluted by sewage during monsoon periods.

Impact studies from developing countries show variations in effectiveness in terms of public health from introducing water and sanitation systems, depending on conditions. Yet, the overall trend is that improved water supply results in reduced mortality and the beneficial impacts are larger when sanitation is introduced. The best results will be gained if health education is also introduced (Juuti and Katko, 2005). The value of providing water and sanitation in developing countries is highlighted in the recent report on delivering the UN WWD Water for Life (2003) challenges, in which cost/benefit ratios for provision of water and sanitation are given (Table 5.5). The conclusion is that there is likely to be a total payback of USD 84 billion a year from the USD 11.3 billion a year investment needed to meet the stated Millennium Development Goals' (MDGs') drinking water and sanitation target.

Locally and regionally, competition for water is increasing. To this must be added the threats to regional and global ecosystems caused by anthropogenic and natural climate change (Cosgrove, 2003). Available global water resources

Table 5.5. **Benefit/cost ratio for interventions in developing regions and Eurasia**

WHO/UNICEF, 2005

Result of intervention	Benefit/cost ratio
Halving the proportion of people without access to improved water sources by 2015	9
Halving the proportion of people without access to improved water sources and improved sanitation by 2015	8
Universal access to improved water and improved sanitation services by 2015	10
Universal access to improved water and improved sanitation, with water disinfected at the point of use by 2015	12
Universal access to a regulated piped water supply and sewage connection in house by 2015	4

are becoming progressively diminished while populations are increasing, leading to greater scarcity and predictions of an increase in conflicts. In 1999 there were reported to be 261 international transboundary basins that together covered 45% of the earth's land surface, encompassing 40% of the world's population, and providing 60% of the earth's entire freshwater volume. A total of 145 countries' land areas fall partially or completely within international basins. Although water wars are not common, the diminishing of water quality or quantity destabilises regions, especially within transboundary basins (Wolf, n.d.). It is postulated (Hassan, 2001) that from a historical perspective, an integrative ethic of water management is now needed. This is due to the current paradox in developed world attitudes to water – a result of the fragmentation of management and a marketing ethos that regards everything (including water) as a commodity and profit as the ultimate objective (Hassan, 2001), and the simultaneous perception of water as a human right. Global co-operation must be based on the real exchange of benefits and cost-sharing, and ethical criteria for established priorities related to water must be created.

Much contemporary thinking about the value of water includes ethical issues such as water as a social or public good or as a commodity (Gleick, 2004; Tipping, Abdm and Tibaijuka, 2005). This is important as water access is recognised as essential in delivering all eight of the Millennium Development Goals (WHO/UNICEF, 2005). Over the past 100 years, the disparity in wealth and opportunity for development within and between nations has had serious implications for the sense of self-worth and hope of many parts of the world. The threat to the well-off is now not only from a territorially based "enemy". The threat is endemic and contagious, and manifested via international terrorism. Conflicts over water are not solely due to governmental policies, but are at once local, among communities and populations, and global. They frequently involve multinational corporations (directly or indirectly involved in the management or exploitation of water resources) and international monetary and regulatory bodies. Commentators in this area stress the need to build institutional capacity to help avoid conflicts over water, and to build the capacity within communities to understand the issues and develop shared responsibilities (Hassan, 2001; Cosgrove, 2003; Wolf, n.d.).

In technological terms, the mode of delivery of water services must shift from the conventional hard engineering (large new assets) approach to a balanced soft-hard and environmental (or ecological) engineering approach that better considers the viability of local, regional and global regimes and accounts properly for whole-life perspectives. For long term sustainability it will be important to transform the management mode of water systems from “technical fixes” to appropriate systems that include community management and encompass a diverse range of delivery options. This means that all stakeholders need to be better informed and included in decision making. In addition to large, hi-tech projects, small, community projects must be considered – various scales are required. Sustainability is about diversity and the overall scope of management must be broadened to better include the social dimensions of water systems. External systems or stresses will be the main change drivers, and of those climate is likely to be the most significant. In Australia for example, droughts and water stress in the main cities of Melbourne, Sydney, Adelaide and Perth have forced the adoption of a whole new range of approaches to managing water. These are based much more on the concepts of reuse, recovery and matching water quality to particular water use, and on educating users (CSIRO, 2004). It could be argued that Australia is currently in the vanguard of innovative water service provision in the developed world.

Sectoral scope

The sectoral scope of this report is principally urban water services and to a lesser extent rural water services. However, with some 75% of the world’s water being used for agriculture, there are issues of allocation and competition for resources (quantity) as well as water quality. Thus agricultural consumption cannot be ignored, even if in-depth consideration of the infrastructure needed for irrigation lies outside the scope of this report. In addition, there are a lot of dual-use water resources and hydropower schemes with many more now envisaged as part of the ambitions of the MDGs. These will not be considered in detail here due to their variability.

Water supply and wastewater management infrastructure for urban areas comprise four major systems:

1. Water abstracted for agricultural use – for rural communities and small urban areas. Most of this is groundwater.

2. Water resources – abstraction (and possibly storage) for human needs. The source can be upland rivers, lakes, lowland surface water, groundwater, sea or brackish sources or from evaporation systems.
3. Water supply network, including inputs from abstraction, treatment, storage and distribution, and outputs, including management of residual sludge.
4. Wastewater system, including stormwater and sanitary drainage, treatment, effluent disposal and management of residual sludge.

Of these, in urban areas in the developed countries, the networks in 3) and 4) are generally the most valuable assets, comprising some 60-80% of the total value of all urban water and wastewater systems. For example, in the United Kingdom, the current value of existing sewage assets alone is some USD 200 billion.

Service standards or levels are important in terms of assessing the current state of and demand for water-related infrastructure. These vary worldwide and are also not static, with ever increasing standards expected in the developed world and a bare minimum standard in a number of other countries. In the developing world, large networks and end-of-pipe treatment plants are being installed, even though "ecosanitation" is likely to be a more appropriate form of infrastructure, particularly in the less dense settlements. This is low-technology using VIP latrines and local water supplies stored and treated with basic but adequate standards. Joining the supply side to the waste side with reuse and recovery, a feature of ecosanitation, also makes nutrient and energy management more efficient. Even in developed countries, "eco-villages" in Sweden aim for a zero emission, supply-based water system. This approach is echoed in the WSSTP (2005) strategic research agenda, and in the 4th World Water Forum (in Mexico, March 2006) where Integrated water Resource Management (IWRM) is seen as a major solution option for the future (Sommen, 2006). Notwithstanding the disadvantages, a number of developing world urban areas were and still are encouraged by developed world consultants, with the tacit support of donor organisations, to utilise large-scale centralised wastewater systems. This is despite the use of precious water to transport the wastes, making it unsuitable in the long term for regions with water scarcity. In many places this has already led to an overexploitation of limited renewable water resources (Werner *et al.*, 2004).

Rural water requires infrastructure systems different from the urban ones outlined above. Although some rural supplies come from surface sources, usually wells or boreholes are drilled and installed to access groundwater. Institutionally the governance and financing arrangements differ considerably from urban areas, and often the same level of service is not available.

To sum up this section, although the majority of the world's population, now and in the future, are likely to live in urban conurbations, there are important water needs in rural areas that also need to be considered. This requires consideration of infrastructure for: all sources of abstraction (surface or groundwater) and storage; water treatment processes; transmission and distribution; wastewater collection and conveyance systems; and wastewater treatment and residuals management.

Geographic scope

Globally the main actors may be nation states, although increasingly multinational organisations seem capable of operating semi-autonomously. Nevertheless, here the most successful countries worldwide will be considered in terms of the future needs for water infrastructure. These are the 30 OECD countries plus China, India, Brazil and Russia. Mention will also be made of states in Central and Eastern Europe and Central Asia (the former Soviet Bloc) as well as some mention of sub-Saharan Africa, as those countries here represent the majority of the less developed countries, which are particularly important with respect to the Millennium Development Goals.

2. Past trends in infrastructure investment

Introduction

Access to water and sanitation infrastructure is reportedly now more equitable than for most other main infrastructure provision (Fay and Yepes, 2003), with an accessibility ratio of high to low income of 1.3 for water and 2.2 for sanitation. Interactions between services are also important, as transport systems are needed to build and service infrastructure and waste systems can confound effective drainage. Energy is required increasingly worldwide, and there are existing and proposed conjunctive use schemes with large water resources and energy generation from hydropower. In developed countries much more pumping of wastewater and high-energy treatment has become common; in Europe this is due to the Urban Wastewater Treatment Directive, and in the United States to high-energy disinfection of sewage effluents. In developing countries the interaction between agricultural demand for water and human direct use is important in rural areas, as is the use of human waste as fertiliser, whereas in urban areas the main problem relates to the lack of solid waste handling systems. The latter situation leads to refuse collecting in wastewater channels, causing blockage, flooding and human health impacts.

Investment in infrastructure has varied greatly globally. In general, water services require high rates of capital and maintenance investment with a low return on assets (typically 5%). Nevertheless, returns are low risk – as illustrated by the English water companies, where there is a high level of indebtedness but good returns for investors. While the populations of much of Western Europe, North America and most of the OECD countries now have effectively full access to water and sanitation services, access by much of the rest of the world is patchy. Services are provided by almost every conceivable mix of public and private involvement and tend to be centralised with large treatment facilities and distribution and collection networks. In the rest of the world, local and very variable services exist for water supplies, often with informal sanitation (open air). This is common even in industrially developing countries such as India. In the recent past most OECD countries have at least attempted to maintain their water assets and extended these where necessary to cope with increasing populations, demands and expectations. Often the capacity of the original systems is stretched due to suburban growth.

The most developed countries now recognise that the large-scale centralised systems may no longer be viable, due to high maintenance costs and resource needs. This is true for both water supply and wastewater infrastructure. In Australia, water management at or near the source of rainfall via direct roof runoff collection and storage, and through grey water recycling and even recycling of sewage at source are all options now part of the portfolio of how best to provide and maintain water supplies. As well as changes in ambient technologies, new water policies are being introduced that establish water markets allowing trade to reallocate water both between users and between sectors (WSAA, 2005).

Various commentators suggest that more dispersed and localised wastewater systems are required even in the major developed cities (*e.g.* Tjandraatmadja *et al.*, 2005) along with nutrient recovery and better control of substances introduced into wastewater systems (Matsui *et al.*, 2001). Although there are arguments over the relative merits of localised (or "on-site") systems for wastewater management, serving individual or small groups of properties – compared with the "end-of-pipe" systems traditionally used – there is a growing usage of on-site sanitation in countries such as the United States. Such systems can recover nutrients and energy and also be linked to local water supply and reuse technologies. In the United States, on-site sanitation systems now comprise some 40% of all new developments (USEPA, 2002). This potentially changes the approach to service provision in the future, with systems being smaller and requiring much less up-front capitalisation for their implementation. Decentralised systems are also better at coping with the need to expand services. In the area of storm water drainage, there is also a growing use of "source control" technologies that handle storm water near the point of generation, *i.e.* locally, also providing opportunities for direct use for, *e.g.*, toilet flushing.

A large number of small wastewater systems will require business models different from the large centralised systems traditionally used. In countries like the United Kingdom and France, moves to decentralisation could be more difficult due to the service providers being larger and concerned

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to maintain their core centralised infrastructure systems. In developing countries, decentralised systems are seen by many as the only affordable option (*e.g.* Werner *et al.*, 2004). Estimates of the average costs of infrastructure provision in developed countries are given by Lee *et al.* (2001) and are summarised in Table 5.6. These figures are undated but presumably are current for 2000 and for French conditions, and relate to service standards that are generally accepted in Europe. The water supply costs do not include large dams or similar infrastructure as this is locally specific.

Table 5.6. **Costs of water supply and wastewater infrastructure for centralised systems**

US dollars

Service	Water supply[1]	Sewage disposal: Combined sewer[1]	Sewage disposal: Separate sanitary sewer[1]	Separate storm water
Networks (cost fraction)	85%	90%	88%	100%
Treatment (cost fraction)	15%	10%	12%	Storage only
Financing costs[2]	Up to 40	15-25	10-16	9-15
Maintenance costs[2]	Up to 45	13-25	8-15	5-13
Operating costs (30% labour)[2]	15-60	30-40	15-35	12-18
Taxes[2]/other	3-15	4	2.5	2
Infrastructure cost per head for 180-210 l/h/d (min.-max.)	700-800 Ave (450-1 800)	1 000-1 300 (900-2 200)	700-900 (650-1 400)	650-700 (970-1 250)

1. Includes centralised treatment system.
2. Costs per 100 m^3 per year.
Source: Lee *et al.*, 2001.

Some advances have been made in providing water and sanitation services elsewhere. The water supply and sanitation decade (1981-90) was reasonably successful in cutting the numbers of people without these services, despite a tripling of population and a sixfold increase in the human use of water (Cosgrove and Rijsberman, 2000). Even so, sanitation provision is not keeping pace with population growth. In parallel, there have been significant investments in wastewater treatment that have improved environments, although in the two most rapidly developing countries, China and India, environmental degradation due to sewage discharges and other impacts is a major problem. Water for food, a major issue, has given rise to an explosion in groundwater use. Globally, almost without exception, centralised water and related services are subsidised even where provided by private companies. In Greece and Spain for example, water is priced at some 25-30% of the true costs, and in the United Kingdom at about 90%. In other countries water endowments cut costs to users, by USD 0.8 in Canada and USD 2.24 in Germany (Lee *et al.*, 2001). This contrasts with the poorest unserviced populations who have to pay high costs for bottled or locally available water. Even in these countries, however, water for irrigation or industry may be subsidised. In India it is estimated that irrigation is subsidised directly (USD 800 million/year) and indirectly through a USD 4 million subsidy for electricity for pumping (Lee *et al.,* 2001). It is suggested that without this the country would starve (New Scientist, 2006). In Europe at least, the water framework directive is supposed to ensure that the full economic costs of water services are passed on to the users by 2015 (Sommen, 2006).

Service standards or levels are key to understanding the recent trends in infrastructure provision, as they dictate forms of service and the performance expected of those services. Overall the approach in the 20th century has been to try to satisfy demand from all sources and latterly to introduce more controls and services to minimise the pollution caused by returning contaminated water into the environment. Only recently has it been recognised that demand management must also go hand in hand with satisfying demand, and that a more integrated and overall approach is needed (*e.g.* WSSTP, 2005; WSAA, 2005). In most OECD countries and in certain developing countries, service standards are specified and may be enshrined in regulations. Investment in infrastructure provision has then been tailored to meet these, via new asset investment or maintenance of existing infrastructure. In recognition of the need for some standardisation, the ISO is developing specifications for service levels in the water and sanitation area (ISO/TC, 2004). Worldwide the most accepted standards are those defined by the WHO for drinking water (WHO, 2004), but these relate to the quality of the water rather than the quantities or the services that provide these.

There has been both an assumption and a desire on the part of the poorest, that developed world water supply and sanitation technologies be applicable worldwide. Apart from the impossibility of providing waterborne sanitation for all – because that would require the use of all available free water sources – other considerations militating against this are cost, energy use and loss of the valuable nutrients contained in sewage (Matsui *et al.*, 2001). Nonetheless, major funders have promoted the use of these technologies and stipulated their use as a condition for lending funds for or funding new infrastructure, along with promoting privatisation of service delivery. There are examples of successes and failures arising from this approach; it is clear that no one technology perspective or business model guarantees success (WDM, 2005). Failures have been attributed to local circumstances, including governance and corruption, poor service provision once a franchise or partnership has been awarded, excessive charging increases, and lack of promised investment. Successes are best illustrated by the English and French models, where investment in water services has been substantial in the past 20 years and there are clear regulatory systems and targets. This may be contrasted with the United States, where there are strong standards but nationally a surprisingly wide variety of providers and forms of provision.

Current evidence indicates a waning of interest on the part of the major private company players in large-scale investment in urban water and sanitation services. The risks and returns appear to be not as favourable as in the past (*e.g.* OECD *et al.*, 2003). Wholesale rural water service investments have never been attractive to the private sector, and private participation is typically via specific activities such the supply and distribution of bottled water or the offering of particular services within the water supply and disposal chain (Water Management Consultants Ltd., 2004). In rural areas local SMEs have a more important role in these services.

Global trends in water resources, supply and consumption

An overview of past trends in selected countries can be found in the Endnote Profile that concludes this chapter.*

The three main drivers behind the expansion of water resources during the 20th century are population growth and increased per capita demand, the increase in irrigated agriculture and industrial development. It has been estimated that at least 54% of accessible runoff is already appropriated for human use, a figure that could rise to 70% by 2025 (Gleick, 1998). Globally the withdrawals of water for irrigation account for some 70-75% of the total while about 20% is for industry and the remainder for domestic use (see Table 5.7). In general, per capita water consumption in developed countries has been decreasing in recent years, reflecting the changes in forms of economic activity and the (relatively) more efficient use of the available water abstracted. In the United States, total per capita withdrawal peaked in the 1980s at about 2 700 m^3/p/a, while actual consumption stands at about 500 m^3/p/a. In spite of this it has been estimated

Table 5.7. **Global water use**

Cubic kilometres

Use	1900	1950	1995	2025
Agriculture				
Withdrawal	500	1 100	2 500	3 200
Consumption	300	700	1 750	2 250
Industry				
Withdrawal	40	200	750	1 200
Consumption	5	20	80	170
Domestic				
Withdrawal	20	90	350	600
Consumption	5	15	50	75
Total				
Withdrawal	600	1 400	3 800	5 200
Consumption	300	750	2 100	2 800

that, assuming a "business as usual" scenario, a significant number of both developed and developing countries will experience moderate to high water stress. Per capita water availability will continue to decline.

The Drinking Water Supply and Sanitation Decade of the 1980s (1981-90), which focused primarily on the underserved populations (80% in rural areas), resulted in nearly USD 100 billion in investments (WHO, 1992), and as a result water sector performance improved. By the end of the decade 1 104 million people had obtained access to safe water, the majority being in rural areas (Dieterich, 2004). Moreover, the number of city dwellers in the developing world with access to adequate water increased by 80%. This still left 204 million in urban areas and 41% of those living in rural areas not served. Now some 1 100 million people do not have access to safe water and 2 600 million do not have access to sanitation (WaterAid, 2005). About 80% of all diseases in the developing world are water related, and it has been estimated that each year they account for 1.7 million deaths and the loss of 49.3 million Disability Adjusted Life Years (DALYs), excluding malaria (UN, 2003) – population increases and urbanisation having wiped out the earlier gains, such as they were. Between 1990 and 2000, access to adequate water supply in developing countries as a whole increased from 73% to 79% (Mainardi, 2003). But these aggregate trends hide disparities. In Africa and Asia, where most of the world's poor are concentrated, access to water supply and sanitation presents a far from comfortable picture. In the developing world and especially Africa, developments in the water sector have not been well targeted, technologies used have been up to 10 times more expensive than necessary, and services have been improved for a few rather than for all (WaterAid, 2005).

Examination of the relationship between income levels and infrastructure coverage across 15 countries shows that as income levels rise from USD 100 to USD 250 per month, coverage of all infrastructure services rises rapidly, with water connections following electricity in terms of priority. There is a marked disparity between urban and rural access and the very poor rarely have any infrastructure services at all (Komives, 2001).

Table 5.8. **Water supply coverage 1994**

Region	Urban population served		Rural population served		Total population served	
	Millions	%	Millions	%	Millions	%
Africa	153	64	173	37	326	46
Latin America and Caribbean	306	88	70	56	376	79
Asia and the Pacific	805	84	1 690	78	2 495	80
Western Asia	51	98	20	69	71	88
Global	1 315	82	1 953	70	3 268	75

Source: Warner, 1997.

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Prior to 1980, water supply management was supply driven, harnessing more and more of the available water resources to supply the rising demands. A notable feature of water resources management was to address the uneven distribution of resources in time and space and to redistribute water when and to where people wanted it. However, some countries have been more successful than others in this respect. Whereas arid rich countries such as the United States and Australia have built over 5 000 m^3 of water storage per capita, and middle-income countries like South Africa, China and Mexico can store about 1 000 m^3 per capita, India by comparison can only store 200 m^3. Given the enormous scale of investment involved, most development projects relied on government funding and management in one form or another. The World Commission on Dams estimated that USD 2 trillion had been spent building some 45 000 dams in the 20th century (WCD, 2 000) and that annual investment was running at USD 40 billion (not all for water resource purposes). Only when resource constraints, economic factors and environmental concerns started to become significant issues did it occur that traditional approaches such as large dams and reservoirs may no longer be the solution.

New water infrastructure projects have become increasingly expensive compared with other alternatives, placing a strain not only on existing budgets but also on future income streams. There has been a growing appreciation that issues of social equity and ecosystem integrity have to be included in decisions.

Systems of public water provision often insulate the public utilities from the influence of the market, restricting their very ability to respond to increasing needs or changes in service standards. Politicians, in responding to equity concerns and/or short-term gain, often keep prices for infrastructure services below cost recovery, making service providers dependent on politically motivated budgets (World Development Report, 2004). Arising from the demands of urban groups of consumers with generally higher living standards and greater political articulation, every increase in water quantity will correspondingly give rise to calls for better quality, and since rising urban demands mean more residential sewage and industrial pollution, every increase in consumption could lead to concurrent deterioration in water quality. Thus the problems can become associated with allocation and management rather than resource development.

The efficiency with which water is used has become a major consideration, especially in urban supply as the scale of losses has become increasingly apparent. A significant percentage of distributed water never reaches the final user but is lost due to leakage. Average leakage rates for Public Water Supply (PWS) range from 10% in Austria, Australia and Denmark to 33% in the Czech Republic (OECD, 1999). In the United Kingdom in the 1980s some 30% of all water was lost from water distribution systems, and in some parts of London that figure reached 60% (*The Guardian,* 2003). Such problems are most acute in long established urban areas with ageing assets. Water infrastructure such as pipes can be expected to last for between 50 and 100 years depending on conditions, implying replacement rates of 2% per annum. Most systems in urban areas were laid at the beginning of the 20th century but replacement work has often been neglected: 0.01% in London and 0.8% in Munich for example (SAM, 2004). A major difficulty is in defining what levels of leakage may be acceptable from "public" mains. In England and Wales, Economic Level of Leakage (ELL) is used to specify targets for the water companies. ELL represents an agreed leakage rate above which it is believed economic to tackle the problem and below which it would supposedly cost more than it would save to deal with. ELL suffers from the notorious difficulty of assigning economic and marginal costs and is a highly contested concept. Typical agreed ELL are of the order of more than 20%. A further problem is leakage from customer supply pipes. Only where there is universal metering does the customer have an incentive to reduce the leakage. In England the water companies have consequently offered to take control of customer supply pipes (and also sewers), in order to ensure that these are better maintained.

Losses from distribution systems are a global problem, but the situation in the developing world is especially acute, with too many people without access to safe and affordable water supplies and sanitation. For a variety of reasons water systems have been unable to keep up with the rapid urbanisation of developing countries. While in the 1980s more people in urban areas gained access to safe drinking water – many countries doubling the provision of new water services – more recently the population has begun to outpace the gains made. In Jakarta the water supply and disposal system was designed for half a million people; in 2000 the city population was more than 15 million (Cosgrove and Rijsberman, 2000). It has been estimated that in 1980 there were some eight cities in the world with populations over 8 million people; by 2015 there will be 36, of which 23 will be in Asia (Brinkhoff, 2004). To add to these difficulties in many major cities in the developing world, piped water supplies are intermittent and do not meet accepted quality guidelines (World Development Report, 2004).

As water for industrial use has become both scarcer and relatively more costly, usage has declined. In Japan industrial water use has dropped by some 25% since the 1970s in spite of increasing industrial output. In the United States there have been similar trends, due in part to improvements in manufacturing technology but also to the changing economic structure of industry. In parts of England (East) and in Sydney, Australia, increases in domestic demand have been met from the serendipitous reduction in industrial water use in the past decade. In Sydney, some 900 000 more inhabitants have not increased the total water used, due to falling industrial use and vigorous demand management initiatives changing domestic fittings and appliances to low water use. However, in transition economies, water use by industry is

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increasing and often use per unit of output is two to three times higher for the same product than in OECD countries. This is generally because these industries are not charged the full economic cost of the services. Similarly, there has been a trend for industries to utilise their own wastewater treatment systems, and in many cases recover waste resources or energy. In Europe and a number of developed countries, this is encouraged by legislation and a desire by companies to achieve environmental accreditation to ISO 14000 or equivalent.

Groundwater is now an important component in Asian economies. A recent estimate has put the agricultural value at some USD 25-30 billion per annum (Shah, 2003, cited in Gleick, 2004). This far exceeds the economic value from surface sources. Table 5.9 shows the dependency on groundwater for a number of regions.

Table 5.9. **Groundwater extraction in selected regions**

	Number of structures extracting groundwater (thousands, 2003)	Average extraction per structure (m^3/yr)	Population dependent on groundwater (%)
India	19 000-26 000	7 900	55-60
Pakistan (Punjab)	500	90 000	60-65
China	3 500	21 500	22-25
Iran	500	58 000	12-18
Mexico	70	414 285	5-6
USA	200	500 000	<1-2

Source: Gleick, 2004.

By volume, four countries account for more than 60% of the world's groundwater abstraction: India, China, Pakistan and the United States. These countries account for 75% of the agricultural usage. Data are, however, not as reliable as they are often for private well abstractions for individual farmers – thus agricultural use is likely to be severely underestimated for many countries like India. Over-abstraction, where withdrawal exceeds recharge, is occurring in a number of Middle Eastern countries and also in Turkey and Mauritania. By 2000 some 25% of Mexico's aquifers were known to be overexploited in arid parts of the country. A similar picture is also expected to be true of India and China in certain regions. In India, Pakistan, China and Iran a significant proportion of the population depends on groundwater abstractions, through a high number of very small structures. In Asia this was part of the "green revolution" of the 1960/70s. In contrast, in Mexico and the United States there are fewer but larger structures controlled by a smaller number of people.

Evidence shows that crop yields in areas using groundwater are invariably greater as these water sources tend to be more stable than surface sources. A recent EU study has highlighted the economic benefits of irrigation and the future challenges from the WFD and CAP (Vecino and Martin, 2004). In areas of Spain for example – where irrigation uses 80% of all water supplied, and for which 20% comes from groundwater – irrigation with the latter leads to crop production five times as economically productive, and provides three times the employment, compared with other areas where there is surface irrigation. The reliability of supplies is estimated to result in twice the economic value of simply increasing the volume; hence opening up groundwater access in India in the 1960/80s has led directly to a stabilisation of agricultural production and been a major part of India's economic development and decline in poverty of rural communities.

In view of the lack of, or poor quality of, groundwater data in these "boom" areas, it is impossible to gauge the possible future macro-level implications of declining availability, falling water tables or quality reductions. Information in this area needs improving, as it is so vital for the economic stability of some of the largest countries in the world (Gleick, 2004).

Over-extraction of groundwater can lead to saline intrusion from adjacent coastal waters, or other naturally or human-contaminated water. There are other problems, such as in Bangladesh, where 22 million people risk being poisoned by naturally occurring arsenic in groundwater. In these areas there may be no alternative but to consume polluted water as there are no other affordable sources, although alternatives are being sought such as direct rainwater harvesting. Arsenic is a more widespread problem in groundwaters and has recently been reported in sources used for supply in Italy, Pakistan, Mexico and China (SAHRA, 2006; Stedman, 2006).

3. Overview of trends in water demand and infrastructure

Introduction

It is apparent that the world is, or will soon be, facing an unprecedented challenge when it comes to water services (see this chapter's Endnote Profile). In part this is due to population growth, but it is also caused by expectations, new demands and climate uncertainty. The recognition that the poorest and those without adequate access to water and sanitation should be appropriately serviced has grown over the last two decades, and is challenging future management and delivery of water-related services. To address the issue, the international community has established Millennium Development Goals against which to gauge investment and progress (UNDP 2000). Target 10, within MDG 7 to "Ensure environmental sustainability", is: "to halve by 2015 the proportion of people without sustainable access to safe drinking water." While this target may be both feasible and on track, it is five times less ambitious than the notion of universal access; even when "average" progress meets this target "the situation for disadvantaged groups is in fact stagnant or deteriorating"

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(Vandemoortle, 2001). This means that the MDG targets could be satisfied without necessarily achieving access for the poorest sectors of society (Water Management Consultants Ltd., 2004). It is also clear that whatever the debates are around the achievement of the MDG, the impetus to meet them will continue to be a major investment driver for the next few years (*e.g.* Sommen, 2006).

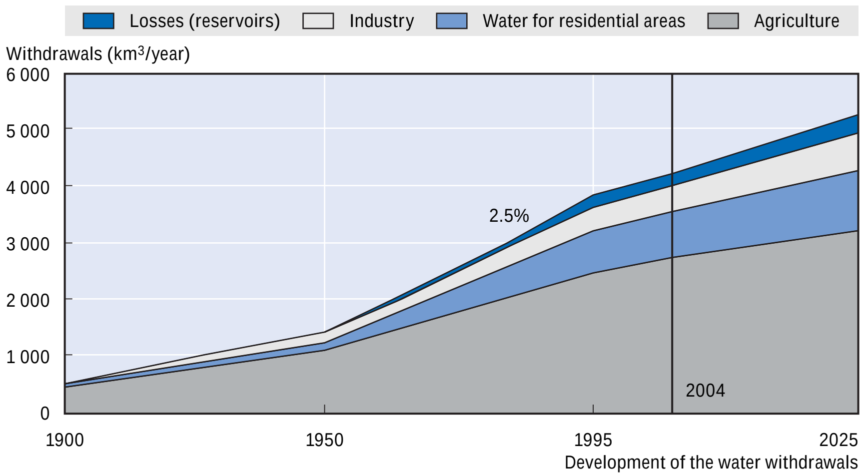
Among the other major challenges facing the water sector are the institutional changes required to modernise and strengthen the legal, policy and administrative arrangements that govern the sector. Water institutions are strongly influenced by factors such as resource endowment, demography, and science and technology. Private sector participation has a relatively strong presence in the delivery of water services in high- and middle-income countries; major cities have some form of involvement although smaller sizes of systems, particularly in LICs, are less attractive (OECD, 2000; Estache and Goicoechea, 2005). The vast majority of private contracts have been granted in urban areas. This trend is most marked in East Asia where there are some concessions and many Build-Operate-Transfer and service deals managed by international private companies. China has been perceived as a potential growth market and in other areas such as Latin America and Eastern Europe, national private enterprise plays and will continue to play an important role. By contrast, low-income and poor countries such as sub-Saharan Africa, South Asia and the Middle East are not attracting much interest from private capital other than in management contracts. Private sector participation is highly concentrated among a few trans-national corporations (TNCs) that are well established in the water sector, with ten companies – all based in OECD countries – holding the majority of contracts. One company for example has more than 25 million customers on four continents (Bakker, 2005).

Future water demand trends

The future demand for and consumption of water will be influenced not just by climatic factors but also by policy decisions, the actions of millions of individuals, the type of and access to water infrastructure and services, changes in technology, and affluence and a whole host of other factors. Projections have been made assuming no radical departures from current practices (Alcamo, Henrichs and Rösch, 2000; Rosengrant, Cai and Cline, 2002). By 2025 water withdrawals in developing countries could increase by 27% over the 1995 figures and in developed countries by 11% (Figure 5.1). Total domestic consumption will increase by 71%, of which more than 90% will be in developing countries; industrial water consumption will also grow faster in developing countries.

In developed countries water for industrial use should decline, due to the changing nature of industrial activity as well as further moves to reduce unit water usage and increase water productivity. The major drivers will be increasingly stringent environmental regulation and the cost of water.

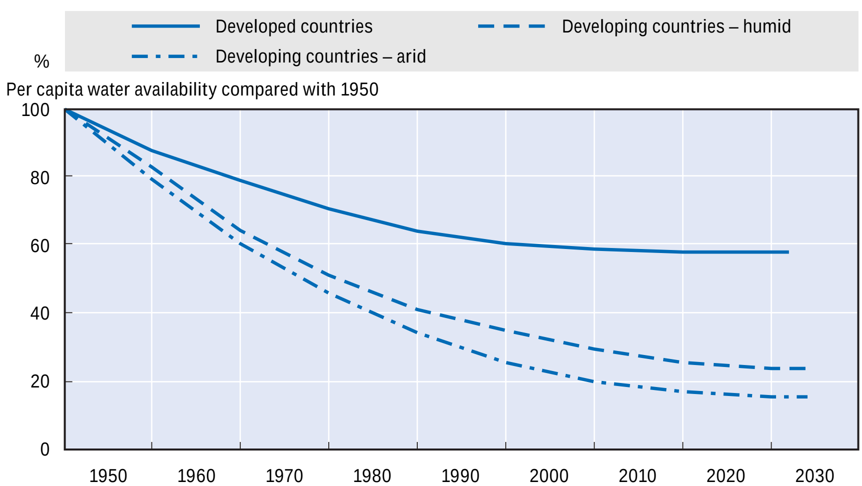
Figure 5.1. **Global water withdrawal predictions**



Source: Shikomanov, 1999; FAO 200.

Figure 5.2. **Global water availability**

Water availability continues to decline (1950-2030)



Source: Bridging Troubled Waters: Assessing the World Bank Water Ressource Strategy, World Bank, 2002.

Domestic consumption will be driven by demographic factors and structural changes related to water intensity increasing with levels of affluence. At the same time, technological changes will lead to improvements in the efficiency of water use and a decline in water intensity over time. In addition, the evolution of key technologies such as desalination may provide new sources to offset demand shortages in some areas. Water for irrigation will, however, continue to be the biggest source of increasing demand in absolute terms.

It is expected that domestic water will account for 21% of global demand in 2025, as against 10% in 1995; industrial use should remain relatively unchanged at around 20%, while agriculture as a proportion will decline from 70% in 1995 to 56% in 2025 (Alcamo, Henrichs and Rösch, 2000). In absolute terms, water consumption in North America and Western and Central Europe will decline along with that in Japan and Australia, a trend that is already well established in Europe (Eurostat, 2003).

Given both India's and China's pace of urbanisation, their demand for water in the domestic sector is expected to double by 2030 with a similar scale of increase in industrial demand (CAS, 2000; Indian Planning Commission, 2002; Briscoe, 2005). For India to meet the increases there will have to be transfers of the current allocation from agriculture to the domestic and industrial sectors. However, the problems this will cause will be exacerbated as most of the domestic growth will be located in the water-scarce areas of the country. In China there will be a target of nil growth in water consumption for irrigation, which coupled with further resource developments should cater for the increases in the irrigated areas.

Trends impacting on water service provision

Crucial for the review of trends is the definition of what are appropriate water and sanitation systems for now and the future. This definition is not straightforward. The earlier details of the populations not connected to formal water supply systems (Table 5.1), showed that worldwide there are apparently between 92% and 100% of people in urban areas who are served by some form of formal water supply service and between 73% and 100% served by sanitation systems. These figures do not show the nature or quality of these services. Tables 5.2 and 5.3 illustrate examples of actual household water and sanitation provision, with very low figures in Africa for access to water within households or within close proximity. Even elsewhere, convenient accessibility to water and sanitation does not come close to the global figures above; there are low figures in Asia, Oceania and South America. In Europe, in countries such as Romania, only some 50% of the population have access to "public" water supplies. There are many people worldwide who, although not in immediate danger of not having access to water supplies or sanitation, may only have access to the most basic of services. Thus the definition of what is appropriate is fundamental to current and future trends in the demand for water, associated services and infrastructure. Worldwide there are moves and perspectives to better match water use to the defined nature of supplies (*e.g.* WSSCC, 2005). This, together with Integrated Water Resources Management (IWRM), is seen as the best way to deliver affordable and sustainable water services for all needs (Sommen, 2006).

Trends in the recent past (late 20th and early 21st centuries) may be considered in terms of:

- Supplying demands for the various sectors and actors described in Section 1, *i.e.*
  - Maintaining demands and needs in developed countries and increasingly influencing these demands.
  - Providing new supplies to those not so far connected in both developed and developing countries, via exploiting new or existing sources and providing new infrastructure.
- Maintaining, renovating and enhancing existing water and wastewater infrastructure networks in areas that already have them:
  - Sustaining and enhancing the capabilities of these systems to deliver better quality services and improved performance (enhanced quality of supply and wastewater treatment, more efficient and cost effective, higher environmental standards and stakeholder engagement, leading to sustainable systems).

Globally, a number of factors have been responsible for changes in the approach adopted to the provision of water services in developed countries in particular and increasingly elsewhere: the recognition of concepts of sustainability and sustainable development, growing awareness of climate change, other socioeconomic pressures, changes in industrial bases and globalisation, and the development and availability of new technologies. Technological developments now make appropriate service provision feasible at reasonable cost, although there are needs for smarter and more robust approaches (WSSTP, 2005). For example, emerging and more efficient desalination processes using membrane bioreactors (MBRs) have been hailed by many as the future way of satisfying water demand. However, these processes use high amounts of energy and discharge concentrated brine effluents that can impact adversely on ecosystems (Harding, 2006). Currently there are more than 7 500 such plants worldwide, 60% of them in the Middle East. Energy needs to run a plant for a medium-sized city, such as Santa Barbara (United States) are some 50 million kWh/yr (California Coastal Commission, 2006) and unit costs are of the order of USD 1 per m^3 of water produced (Twort, Ratnayaka and Brandt, 2000), which is up to ten times the cost from other sources. Recently plans for a new desalination plant in Sydney, Australia were shelved on environmental grounds following public opposition; similar objections were also cited for the rejection of a proposed plant in London.

It is difficult for water utilities to generate sufficient internal revenues to ensure basic financial sustainability. There are conflicting priorities for national government investment, and it is easy to postpone water investments. The sector has a high level of indebtedness, and its institutions

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have poor creditworthiness. It is also true that the supply of finance influences the level of investments – project sponsors would make greater efforts if they knew that funds were available on acceptable terms. The profile of urban water investment projects typically involves a high initial capital outlay, followed by a very long payback period from long-lived assets. As a result, the risk of repayment default is high relative to many other projects. In many developing countries, borrowing in local currency is only available at short maturities that do not match the long-term financing needs of water projects. When countries borrow in foreign currency, they must repay the debt using revenues generated in the local currency. There are a number of examples where an unfavourable movement in the exchange rate has triggered payment default in water projects (*e.g.* Argentina). However, the fundamental root of the finance problem in the water sector is poor governance. Providers of centralised water and wastewater services are monopolists by nature, and therefore require careful regulation. The information asymmetry between governments and water utilities, and the political sensitivity of water pricing, leave the sector vulnerable to *ad hoc* politics and social criticism. As a result, the sector often suffers from a high level of political interference, and a confusion of its social, environmental and commercial aims.

Decentralisation, a worthy aim in a sector of this kind, has led to a devolution of responsibilities for service to sub-sovereign levels of government, but without a commensurate allocation of the required financial means. Water utilities often lack operational autonomy, and their relationship with their political masters is ambiguous. They often have a poor management structure and find it difficult to attract the best staff. They are frequently in a poor financial condition because they are unable or unwilling to charge customers the economic rate for their services, and this then prevents effective reinvestment. Politicians often burden the sector with financial and regulatory arrangements that are *ad hoc*, unpredictable and not sustainable. That makes it impossible for water utilities to properly maintain their assets or attract necessary finance, and leaves them dependent on the fickleness of governments when it comes to funding their new investments. Lack of clarity about ownership of assets is often an additional obstacle to investment. It is true that the water sector may present opportunities for low-cost investments with a quick return. As this experience shows, financing water infrastructure is not restricted to one-off capital investments: sizeable recurrent spending is also required to operate and maintain the assets. If these outlays are not made, the infrastructure may deteriorate and even collapse. There is a growing acceptance of the need for full cost recovery in water services, but this must be done in a way that safeguards the needs of the poor. Valuing water has become critical to optimising investment and obtaining viable private sector participation in the efforts to raise the needed projected investments of USD 180 billion per year until 2025.

The emerging trends driving investment needs may be distinguished by the nature of the various country contexts. Broadly speaking it is possible to see differences between developed economies in high-income countries, transition economies in middle-income countries, and developing economies in low-income countries. In developed economies generally, water service coverage rates are high and there are corresponding concerns over the maintenance of existing assets, whether urban or rural. At the same time a new wave of (sub)urbanisation, responding to demographic changes, rising levels of affluence and expectations, is driving needs for investment in new infrastructure provision. Thus provision for new growth is a substantial driver. Coupled with this is a realisation of the growing scarcity and competition for resources, prompting interest in demand management and (in some cases) calls for “closing the water cycle” (WSSTP, 2005). There are few signs as yet however that this is being tackled in the most developed countries other than Sweden and Australia, although it seems to be a major perspective for the 4th World Water Forum (Sommen, 2006).

The present diversity of organisational forms of institutions will continue to be a feature of the industry in the future. There will, however, be substantial changes. In Europe for example, drivers such as the WFD and even climate change might be expected to prompt organisational change with respect to scale of operations, but not asset ownership changes. Regulation of the industry and of companies providing services will probably become an increasing feature of service provision as governments seek to ensure that services are delivered efficiently and cost-effectively, while at the same time continuing to move towards full cost recovery. Affordability ratios (spending on water and sewage as a proportion of household budgets) in Western Europe are in the 1-1.5% range, around 1% in Northern Europe (Germany = 1.2%) and below 1% in southern EU countries. In England the average government target is around 3%, but in some areas retired citizens are paying as much as 7%. By contrast the ratio is 0.5% in the United States but rises to as much as 3% in less well developed economies (EBRD, 2005). A number of agencies use figures of 3%, with a maximum of 5% in some cases. At the same time, in developing countries the ratio of revenues to costs in the water sector stands at approximately 0.3 (Hoornweg, 2004). Environmental protection and pollution control could also have profound impacts on future service. The best available exemplar of this is the WFD in Europe. Its full cost impact is still a matter of discussion; however, one estimate suggests it will cost some USD 300 billion to implement by 2017 (WSSTP, 2005; SAM, 2004). It seems that the adoption of increasingly stringent environmental protection measures is in some ways a reflection of societal expectations and norms and concerns about the nature of sustainability, and a product of a wealthier society. The importance of these perspectives in high-income countries and their potential impact on other economies should not be underestimated, as it is the developed countries that exert the greatest influence on global norms and often set the conditions of engagement that others are expected to aspire to and adopt.

In transition economies, such as the EECCA, there are a set of similar drivers and concerns. However, these are modulated by the need to improve service coverage and at the same time address the residual problems of poor governance, infrastructure and organisational neglect and inefficiency that have resulted in the continuing deterioration of the asset base. Following a meeting in Almaty in October 2000, EECCA and other ministers and senior representatives from several OECD countries, and senior officials from international financial institutions, international organisations, NGOs and the private sector recognised the critical condition of the urban water supply and sanitation sector in EECCA and endorsed "Guiding Principles for the Reform of the Urban Water Supply and Sanitation Sector in the NIS". Since then and in preparation for a five-year review meeting in November 2005, the state of the water assets has been further reviewed and found to be continuing to decline (OECD, 2005b).

Thus the emphasis may need to be on replacement rather than maintenance for these countries and many that recently accessed the EU, as the means of improving service and addressing environmental pollution. The need for new investment in infrastructure coupled with the low rates of cost recovery and other factors has focused attention on the corresponding need for capacity building and to restructure the way in which services are delivered. There is a direct relationship between collection rates and affordability (Frankhauser and Tepic, 2005), and poor revenue collection affects almost all of the countries in the former Eastern Bloc. There have been drives for the reorganisation of water services to encourage greater levels of private sector participation, through measures such as corporatisation, concessions and leases and other forms of contract, as a way of freeing the sector up from state control or reliance on state financing.

In developing economies there is an even greater need to extend basic services to burgeoning populations, often in rapidly urbanising situations. Here the need for basic services tends to take precedence over other concerns. Thus there is less of an emphasis on institutional forms and more on partnerships and capacity building, although the institutional and legal frameworks have needed reform in order to facilitate improvement of service provision. In order to meet the MDG, annual spending on water and sanitation needs to double, from around USD 14 billion to USD 30 billion, which indicates that there is a funding gap of some USD 16 billion per year to be met (WaterAid, 2005), at a time when aid from donor countries is generally in decline.

Investment needs

The estimation of future investment needs here has depended more on the availability of information than on sophisticated estimation methodologies. Information is often most readily available from central sources such as industry regulators. The reliability and usefulness of information become problematic when the sources are not centralised, where there are multiple sources of information and where several bodies and agencies are involved. Ideally, expenditure information should distinguish between operation and maintenance and capital expenditure, rarely available. In addition, it is useful to identify expenditures driven by the need for new services – growth, environmental regulation and pollution control as well as the requirements for providing the base service. This detailed information is seldom readily available; thus some of the estimates given below should be considered as indicative only and within orders of magnitude. The levels of investment and expenditure required for the proper provision of water services are substantial and growing. The role of the international finance community is often crucial for transition and developing economies even where the proportion of required investment may be limited, as it has the ability to leverage local funding to support investment.

Estimates of the future demand for infrastructure services for the first decade of the 21st century, which include water services, have been made based on demand rather than measures of need (Fay and Yepes, 2003). It was noted that water and sanitation have dropped in importance relative to the rest of infrastructure stocks as incomes have increased. In deriving investment needs, account was taken not just of the provision of new infrastructure but also of maintenance needs, estimated at 3% of the replacement cost of capital stock for water and sanitation. Fay and Yepes (2003) estimated that water and sanitation should add up to 2% of GDP, noting that their figure was substantially higher than a previous estimate of 0.4% of GDP for middle-income countries. Adjusting the 2% of GDP to reflect the differences they note between high-, middle- and low-income countries indicates that the amounts to be spent on new infrastructure and maintenance would be 0.4% of GDP for high-income countries, 1.9% for middle-income countries and 2.5% for low-income countries. However, there is some ambiguity in the published figures.

In the following sections examples of the investment requirements for certain OECD and other important countries are discussed on the basis of present trends.

United States

The major factors driving capital investments are regulatory compliance, growth and the age of the infrastructure, accounting for 7%, 40% and 30% of expenditure (Brow, 2001). However, these figures reflect expenditure rather than

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need. Various estimates of the required levels of expenditure have been made in recent years (Table 5.10). These have included the EPA's periodic "needs survey" of drinking water and wastewater systems, estimates by the Water Infrastructure Network (WIN) and the American Water Works Association, and the Congressional Budget Office. The Water Infrastructure Network report (WIN, 2000) estimated that drinking water utilities need to spend USD 24 billion per year for the next 20 years on infrastructure but that currently the expenditure is USD 13 billion per year. For wastewater systems the figures are USD 22 billion and USD 10 billion per year respectively, leaving an overall gap of USD 23 billion per year over 20 years (Johnson, 2004). These amounts dwarf the existing level of funding, and federal subsidies used to supplement user fees and help finance capital investments are unlikely to address the real causes of inadequate maintenance: the institutional arrangements and managerial practices (Levin *et al.*, 2002). The EPA's own gap analysis, the 2003 Needs Assessment, is in substantial agreement with the WIN and the Congressional Budget Office estimates (EPA, 2005). All indicate that there is a need for substantial investments to upgrade or replace the water infrastructure (Levin *et al.*, 2002) in order to ensure compliance with quality standards prescribed by the Safe Drinking Water Act. The EPA estimated that drinking water utilities will spend USD 154 – 446 billion up to 2019 and wastewater systems USD 331-450 billion over the same period in order to meet the required standards. In addition a further USD 17.5 billion is required to replace lead service pipes and USD 1.2 billion to harden facilities in order to improve security. In addition, there are the operation and maintenance costs that have been estimated at USD 29 billion for drinking water and USD 24 billion for wastewater annually (CBO, 2001). The estimates approximate to a spending of 0.75% of GDP. Affordability ratios for water and sewage services are approximately 0.5%.

Table 5.10. **Estimates of average annual costs for investment in water systems to 2019**

2001 dollars

Source	Water supply (USD million)	Wastewater (USD million)	Annual amount (USD million)	Total
Congressional Budget Office	12 000-20 500	14 900-22 300	26 900-42 700	538 000-854 000
Water Infrastructure Network	20 900	19 200	40 100	802 000
EPA Needs Survey	7 700-22 300	16 550-22 500	24 250-44 800	503 700-1 014 700

Source: Authors.

Since 1997 a loan programme of USD 1 billion has been authorised annually under the Drinking Water State Revolving Fund for wastewater projects. Concerns about the ability to raise the necessary finances are now leading US municipalities to consider privatisation.

United Kingdom

In England and Wales (privatised) the amounts spent and projected expenditures on provision of water services are shown in Table 5.11 (Ofwat, 2005). The amounts take into account obligations to meet various European Union Directives in future years. In Scotland (public water supply) an amount of GBP 1.8 billion is being invested between 2002 and 2006 with a further GBP 2.1 billion for the period 2006-10 at 2003-04 prices (WICS, 2005). Table 5.10 also shows estimates for the province of Northern Ireland (public). The total corresponds to some 0.72% of GDP at 2005 values. Projected increases are attributable to meeting environmental obligations but the impact of the EU Water Framework Directive is not included, as this will have to be taken into account only post 2010. Estimates for this vary, but are around GBP 30 billion. For the average household the amounts paid for water and sewage services represent an affordability ratio of approximately 1%, in line with European averages; for the poorest however, this can be as high as 10%.

Table 5.11. **Expenditure on UK water services**

GBP millions, 2002-03 prices

	Region	2000-05	2005-10
Average annual capital investment	England and Wales	3 300	3 365
	Scotland	360	525
	Northern Ireland	107	114
Average annual operating expenditure	England and Wales	2 800	2 953
	Scotland	310	410
	Northern Ireland	256	227
Total annual expenditure	England and Wales	6 100	6 318
	Scotland	670	935
	Northern Ireland	363	341
	Total	7 133	7 594

Source: Authors.

Of the capital expenditure, 51% is for the base service, 17% for growth and 32% for quality enhancements.

Central and Eastern Europe

This section is based on a recent report on the EECCA region five years on from the Almaty meeting (OECD, 2005b). The report looked at the costs involved in meeting the MDG in the EECCA countries. Also included were attempts to calculate an all-in cost (referred to as the "total costs") that include O&M and reinvestment costs. The "total costs" were the sum of "MDG costs" over the period 2002-15 (14 years) plus O&M costs of the existing system over the period 2000-20 (21 years), plus O&M costs of new extensions and additional

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facilities to be built over the period 2000-20, plus reinvestment costs over the period 2000-20 – *i.e.* investment costs needed to maintain the same level of quality/service of the existing infrastructure. The estimate was prepared by COWI (OECD, 2005). The estimates did not include such costs under the "MDG costs", where the level of quality/service is assumed to be improved above the current level. This cost estimate corresponds to an aggregate of costs over two different periods, 14 and 21 years. It is this estimate that COWI uses to explore the feasibility of financing the cost of reaching Target 10, Table 5.12. The annual "total costs" estimates per country are obtained by dividing the "total costs" estimate by 20.

Table 5.12. **Water supply and sanitation estimates for EECCA countries**

Million euros

	Water supply		Sanitation		WSS		Total as % of GDP
	Total	Per capita	Total	Per capita	Total	Per capita	
Armenia	58	18.1	26	7.9	84	26.0	2.49
Azerbaijan	102	12.8	87	10.9	189	24.0	2.20
Belarus	211	20.9	91	9.0	302	30.0	1.39
Georgia	69	15.3	29	6.3	98	22.0	2.59
Kazakhstan	233	16.1	100	6.9	333	23.0	0.80
Kyrgyz Republic	80	16.0	30	6.0	110	22.0	6.00
Moldova	44	10.2	26	6.1	70	16.0	3.02
Russian Federation	2 408	16.6	1 254	8.6	3 662	25.0	0.32
Tajikistan	85	13.1	32	4.9	117	18.0	6.26
Turkmenistan	120	22.7	32	6.1	152	29.0	1.37
Ukraine	868	18.0	384	8.0	1 252	26.0	1.89
Uzbekistan	411	16.5	142	5.7	553	22.0	6.28
Total	**4 689**	**16.3**	**2 233**	**7.2**	**6 922**	**23.6**	**2.88**

Source: OECD, 2005b.

The report notes that the annual "total costs" estimate of EUR 6.9 billion per year appears out of proportion with the so-called "MDG costs": over a 14-year period, it amounts to nearly EUR 97 billion, more than six times the "MDG costs". This reinforces the contention that the real challenge for the EECCA regions in the years to come lies much more with the O&M of the water supply and sanitation (WSS) systems and maintaining the existing infrastructure at its current level of quality/service than with extension costs or costs incurred to improve the current level of quality/service and bring it to an "MDG Target 10 compliant" level.

The final column reveals what might be considered some anomalous results, in that some appear too low. For example, for the Russian Federation, 0.32% of GDP does not accord well with the situation outlined in Russia's

Endnote Profile at the end of this chapter. Other estimates would appear to be high, perhaps reflecting the scale of the situation to be addressed. As the report noted (OECD, 2005b), the detailed estimates for specific countries show significant discrepancies that can be attributed to a different understanding of the types of costs to be included and to different calculation methods. In addition, the study suggests that even raising the finance to operate and maintain the infrastructure in its present poor state – a much less ambitious challenge than achieving the water-related MDGs – would pose major problems for a number of EECCA countries.

Canada

A report by Infrastructure Canada (2004b) noted that the dearth of reliable, comparable, comprehensive and objective data and information means that it is difficult to estimate that country's infrastructure needs. This has led to discrepancies between the various existing estimates. While a number of studies have reported on the overall deficit of infrastructure in general, fewer address the state of water infrastructure specifically. It is difficult to determine what the total level of current expenditure is for operation, maintenance and new infrastructure. The discrepancies make it difficult if not impossible to arrive at one overarching, comprehensive figure. In reviewing the literature on estimated needs and replacement costs for water infrastructure, Infrastructure Canada (2004a) indicated that the available figures were neither persuasive nor comparable. The report noted estimates of CAD 38-39 billion for the maintenance of existing capital stocks and services, and CAD 88.4 billion for new and upgraded infrastructure over a 15-year period. By 2003 the total was said to amount to CAD 10 billion per year, highlighting the fact that despite the data problems the amounts required would clearly run into billions. The Canadian Water and Wastewater Association reported that an annual investment of CAD 5.8 billion up to 2018 would be required for underground infrastructure. There would also be a CAD 28 billion infrastructure need for municipal water systems and CAD 60.4 billion debt for wastewater systems from 1997 to 2012. This was derived from statistics of the size of the industry, the population served and levels of service provided. The National Round Table on the Environment and the Economy (1996) study found that existing funds are used to address only the critical infrastructure needs, leaving an unmet infrastructure need to ensure that the existing stock is maintained ranging from CAD 38 to 49 billion, and capital costs for the following 20 years would be in the order of CAD 70-90 billion. New capital demand will exceed CAD 41 billion by 2015. Therefore total capital requirements for water and wastewater infrastructure will be CAD 79-90 billion over the next 20 years. This assumes static market conditions; the effect of other measures to curtail demand could reduce the estimates by 10-16%. A Canada West Foundation report (Vander Ploeg, 2003) indicated that some 60% of the estimated shortfall between current and required funding of all municipal infrastructure would be required to bring the water infrastructure up to acceptable standards. Estimates of total infrastructure debt range between CAD 57 billion and CAD 125 billion (Vander Ploeg, 2003), implying amounts of between CAD 34 billion and CAD 75 billion for water infrastructure. Again this does not include current levels of funding but rather the accumulated shortfall.

Infrastructure Canada (2004a) noted the growing difficulties in financing such investments, which is partly due to under-charging for services but also due to an inability to increase municipal incomes and offset falling provincial and federal transfers. This has led to a growing interest in alternative mechanisms for infrastructure financing. Some public-private partnerships of various kinds have been implemented, often attracting considerable opposition (CUPE, 2005). It now appears necessary to address the challenges related to ageing and inadequate water infrastructure. The federal government is aware of the problem and there have been moves to increase funding, for instance through the establishment of the Infrastructure Canada Program, the Green Municipal Investment Fund, the Green Municipal Enabling Fund and the Municipal Rural Infrastructure Fund. The 2003 federal budget allocated CAD 3 billion for investment in infrastructure generally on top of the previous investment of CAD 5 billion announced in 2001. However, according to the Canadian Council of Professional Engineers, this fails to adequately address the burgeoning infrastructure deficit; increased levels of expenditure are required for the modernisation of water and wastewater treatment infrastructure.

Based on the figures presented above, investments of anything between CAD 34 billion and CAD 90 billion could be required over 20 years just to meet the infrastructure deficit. These figures do not include current levels of investment nor operational and maintenance costs. Taking the CAD 10 billion per year figure, this would imply required investments of approximately 0.6% of GDP – an indicative figure given the caveats that various reports have noted.

However, it is important to note that in 2002, with the creation of Infrastructure Canada, the government of Canada formally confirmed that public infrastructure renewal had become a priority of the federal government. The new federal department was established to provide a focal point for the government of Canada on infrastructure policies, programmes and research. Since its inception it has been working with other provinces, territories, municipalities, First Nations, professional associations, non-governmental organisations, researchers and the private sector to improve Canada's physical infrastructure. Through Infrastructure Canada's funding programmes the federal government has made significant investments in public infrastructure, including water infrastructure, over the past few years. To date, the department has announced investments of over CAD 350 million for water and sewage treatment infrastructure under the Canada Strategic Infrastructure Fund, and just under CAD 1 billion under the Infrastructure Canada Program. Significant investments in water and wastewater infrastructure are also being made as a result of the department's CAD 1 billion Municipal Rural Infrastructure Fund announced in 2003. All of these investments are complemented by the funding programmes and other activities of other federal government departments with responsibilities regarding water and sewage treatment infrastructure, including Indian and Northern Affairs Canada and Environment Canada. (For a fuller discussion of the roles, responsibilities and activities of various federal government departments and agencies *vis-à-vis* water, wastewater and related infrastructure, see "Infrastructure Canada: Enhancing Knowledge about Public Infrastructure – Perspectives in the Federal Family", 2002, available at: *www.infrastructure.gc.ca/research*.)

India

The annual requirement for rehabilitating existing infrastructure is estimated to be USD 4.6 billion, while the India Water Vision expects new investments to cost about USD 4.14 billion per year. Annual allocations in the past have been between USD 0.2 billion and USD 3.9 billion a year (Planning Commission, 2002). A large part of the budgeted amounts is spent on recurrent costs for personnel, electricity and subsidies, and not on the needed maintenance. Water Aid (2005) has estimated that the annual financing need for domestic water and sanitation is some USD 5.05 billion but that only USD 2 950 million is actually being spent, leaving a funding gap of USD 2 100 million. However, a serious problem in most developing countries including India is the failure to utilise the budgets already available; often these are some 30-65% of the actual budget. Based on preliminary estimates, meeting the MDG target in urban areas would require an investment of USD 21.8 billion up to 2017 and recurrent expenditures of about USD 21.1 billion over the same period. In the rural areas the figures would be USD 16.5 billion and USD 15.6 billion respectively. It is unclear what these figures imply for the financing needs for water services over the coming decades. A preliminary estimate has been arrived at by using these figures and making some assumptions (Table 5.13).

This total in Table 5.13 is 0.71% of GDP. While this shows a certain consistency with other country estimates above, it is conjectural and a first order estimate. It does, however, indicate the scale of the financing challenge facing the country, given its current levels of expenditure.

The potential for collapse in groundwater for irrigation from the current over-abstraction may also require significant investments if alternatives are to be developed. An obvious option is to better collect monsoon rains, either in river networks or using other local storage options. Investment costs would be substantial; one estimate of the former approaches USD 200 billion. Needs in

Table 5.13. **Estimated annual investment needs in India**

USD millions

	Rehabilitation of existing infrastructure	New infrastructure investment	MDG urban areas	MDG rural areas	Total
Capital investment	4 600	4 140	1 820	1 370	11 930
Operational expenditure	4 370[1]	3 930[1]	1 750	1 300	11 350
Total	**8 970**	**8 070**	**3 550**	**2 670**	**23 280**

1. Using the ratio of 0.95 of capital expenditure derived from the MDG estimates.

Source: Authors.

this area are not considered further in this report; however, investments in dealing with irrigation needs if and when these groundwater sources fail will be prodigious.

China

According to the Chinese government, expenditure on what are called environmental goods and services have been rising steadily over the past decade as the country has sought to address the problems associated with water shortages, supply, treatment and pollution. In the 10th Five Year Plan (2001-05) an amount of USD 84.5 billion was budgeted, to be followed in the 11th Plan by USD 157 billion or 1.5% of GDP. In 2003 the estimated expenditure amounted to 1.39% of GDP (China, 2005). However, this covers all environmental goods and services, not just water, and it is unclear what other sums at provincial and municipal level should be included. This needs to be increased, probably to around 2% of GDP for air and water pollution control to 2020, and much greater allocations need to be made for basic capacity building (IBRD/WB, 2001). In the 10th Five Year Plan the budget outlay on water supply and wastewater treatment was USD 33 billion. In the 11th Plan a further USD 12.1 billion has been budgeted for water supply and USD 8.37 billion for wastewater treatment associated with three major water supply and wastewater projects. The 11th Five Year Plan (2006-10) sets as a target access to safe drinking water for 98% coverage of urban residents and 60% for rural residents. Recently the Chinese vice-minister of construction said that urban water supply needs USD 250 billion of investment, although the time scale was not indicated. Half of all wastewater is not treated and around 661 cities have no wastewater treatment systems. An estimated USD 10.4 billion is needed to construct the required facilities to meet these needs (China Economic Net, 2005). If 1% of GDP were to be spent annually on meeting the capital, operational and maintenance requirements, the annual figure would be USD 71.34 billion or USD 356.7 billion over a five-year period. If the amounts given above to be spent on urban water supply and wastewater treatment were spent over the next 10 years on new works, this would amount to approximately

USD 130 billion, implying an amount of USD 220 billion for the maintenance and operation of existing systems. Given that the 2004 total state expenditure was USD 3 425 billion per annum, an expenditure of USD 71.34 billion would represent approximately 2% of the state expenditure, which would seem reasonable.

In order to facilitate this process, reforms of the financing and investment structure of the water industry are under way to encourage a range of investment and participation mechanisms for both local and foreign enterprises. A large proportion of the funds to develop China's water infrastructure are expected to be raised from overseas investment, loans and market financing, despite current low private participation. A key factor in attracting investment will be the reform of property rights and transforming government's role into that of a regulator responsible for quality, price, service, rights and competition rather than a services supplier. There appear to be no readily available figures for the ongoing operation and maintenance funding requirements for the country, although it is reasonable to assume that the budget allocations do include the operational expenditures.

Brazil

According to Almeida and Mulder (2005), public investment in water/sanitation has fallen over time, from 0.3-0.4% of GDP in the 1970s and 80s to 0.2% during 1999-2002, and 0.1% in 2003. This drop was mainly due to ongoing fiscal consolidation, which affected investment spending more adversely than current expenditure, being relatively harder to retrench. Preliminary data suggest that spending levels have increased in 2004. Investment is also discouraged by the externalities associated with the provision of sewage and water treatment services, and because water/sanitation networks are costly, investment maturities are long, and rates of return are relatively low. More importantly, the drop in public investment has not been compensated by an increase in private investment, which can be attributed predominantly to a lack of clarity about which level of government is responsible for service delivery and regulation in the sector. This is particularly acute in the metropolitan regions, which straddle municipal borders. As a result, no regulatory framework or regulatory agency is currently available for this sector. The National Water Agency (ANA), created in 2001, is responsible for managing and regulating surface water resources but has no purview over water/sanitation services.

Water sector investment requirements

World Bank Research Working Paper 3102 (Fay and Yepes, 2003) suggests that over the period 2005-10 for the developing world an amount totalling the equivalent of 2% of GDP for all developing countries would be required to be invested in the maintenance of existing and new infrastructure, equivalent

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to 0.44% of GDP annually. For the world the equivalent figures are 0.6% of GDP totalled over five years or 0.12% of GDP annually. From Annex II of the same report the calculated percentages of GDP given are set out in Table 5.14.

Table 5.14. **Expenditure on water and sanitation as a percentage of GDP**

	New infrastructure			Maintenance			Total
	Water	Sanitation	Total	Water	Sanitation	Total	
East Asia and Pacific	0.07	0.1	0.17	0.13	0.15	0.28	0.45
South Asia	0.21	0.19	0.40	0.36	0.26	0.62	1.02
Europe and Central Asia	0.02	0.05	0.07	0.10	0.18	0.18	0.25
Middle East and North Africa	0.06	0.11	0.17	0.10	0.16	0.26	0.43
Sub-Saharan Africa	0.15	0.27	0.42	0.20	0.35	0.55	0.97
Latin America and Caribbean	0.03	0.05	0.08	0.05	0.08	0.13	0.21
High income	0.00	0.00	0.00	0.01	0.02	0.03	0.03
Low income	0.19	0.24	0.43	0.32	0.35	0.67	1.10
Middle income	0.04	0.06	0.10	0.09	0.12	0.21	0.31
Developing regions	0.07	0.10	0.17	0.13	0.16	0.29	0.46
World	**0.02**	**0.02**	**0.04**	**0.04**	**0.05**	**0.09**	**0.13**

Source: Fay and Yepes, 2003.

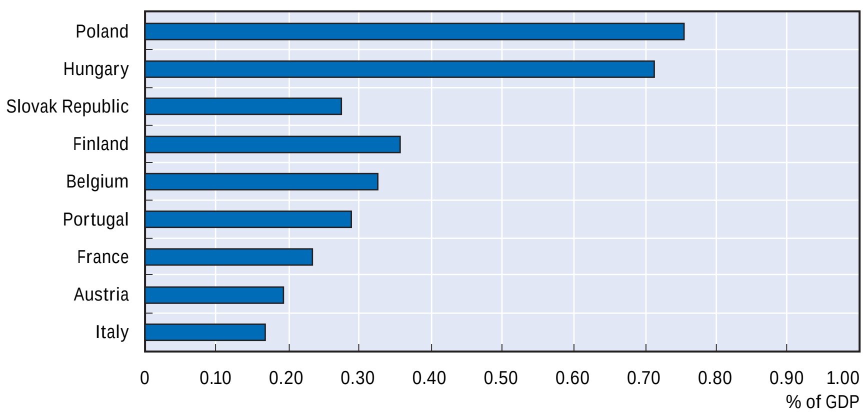
These estimates appear to be substantially lower than the figures reported in the preceding section. Based on detailed estimates of allowed expenditure in the United Kingdom and in the case of the United States on a Needs Survey (EPA, 2005), the equivalent figures were 0.72% and 0.75% of GDP respectively, although in Canada it is about 0.6%. The figure for the United Kingdom is further supported by rough estimates of required maintenance expenditures based on water sector asset values. The value of assets in England and Wales is in excess of GBP 200 billion, based on 3% (Fay and Yepes, 2003) of asset value being spent on maintenance. This implies an expenditure of GBP 6 billion per annum, or the equivalent 0.6% of GDP, excluding new investments and expenditures required for Scotland and Northern Ireland. Thus there is a strong contrast with the figure of 0.03% of GDP for high-income countries given in the table above.

According to Dangeard (2003): "There are few reliable data on water distribution and water pollution abatement expenses as a percentage of GDP. The figures in international sources depend on the sector covered: does it include urban water or also irrigation? Does it cover services and investments? Orders of magnitude concur on some USD 30 billion per year for developing countries investment expenses, the equivalent figure from Fay and Yepes is USD 13.8 billion per year. Thus, surprisingly, developing countries do not seem to devote a higher percentage of GDP for water infrastructure than industrialised countries. A figure for China's pollution abatement expenses given by the National Environment

Protection Agency is close to 1%, which seems low, although increasing. India's expenditure is believed to be less than 1% of GDP. *In France, water expenses of private sector and administrations are 1.2-1.5% of GDP*" (emphasis added).

There is further corroboration that per capita expenditures on water and sanitation in high- and middle-income countries are greater than the indicated figures in Table 5.14. An analysis of Eurostat data on environmental protection expenditure (public and private sectors) indicates a range of between 0.16% and 0.35% of GDP for high-income (average 0.26%) and between 0.27% and 0.75% of GDP for middle-income (average 0.58%) countries on wastewater (sanitation), see Figure 5.3. Given the limitations of the data sets reported by Eurostat, these figures are likely to under-represent actual expenditures. And they only cover wastewater (sanitation); there are no comparable statistics for water supply expenditures. Assuming that expenditure on water supply mirrors that of wastewater, the range would be 0.32%-0.75% and 0.54%-1.5% of GDP respectively for water and sanitation combined.

Figure 5.3. **Total expenditure on wastewater as percentage of GDP**



Source: Authors, based on data from Eurostat.

In 2003 an OECD report stated: "In the OECD countries as a whole the expenditure of the water sector exceeds USD 250 billion per year, taking into account all direct expenditure related to water for domestic, industrial and agricultural use". In the area of pollution abatement and control (PAC), investment and operating expenditure related to water (*i.e.* sewage and wastewater treatment) ranges between 0.3 and 1% of GDP... Most such expenditure is public expenditure, with private expenditure mostly limited to that part of industry and households treating their own wastewater. Water supply and irrigation expenditure are of the same order of magnitude as PAC expenditure.

Table 5.15. **Investment and current expenditure on wastewater pollution abatement and control, selected countries, late 1990s**

	Total[1]			Public sector[2]				Business sector		
	Year	Per capita	‰ GDP	Year	Per capita	‰ GDP	Investment ‰ GDP	Year	Per capita	‰ GDP
Mexico[3]	. .	. .	. .	2000	1.8	0.2	0.1	. .	. .	. .
United States	1994	161.8	6.0	1994	105.0	3.9	1.8	1999	23.4	0.7
Japan	. .	. .	. .	1999	84.1	3.3	. .	. .	. .	. .
Korea	2000	116.3	6.6	2000	80.8	4.6	3.6	2000	35.5	2.0
Australia	. .	. .	. .	2000	36.7	1.4	0.6	. .	. .	. .
Austria[3]	2000	202.8	7.5	2000	117.2	4.3	1.9	2000	47.2	1.4
Belgium	2000	111.4	4.3	2000	74.3	2.8	1.9	2000	29.6	1.1
Denmark	. .	. .	. .	2000	123.0	4.3	1.6	. .	. .	. .
Finland	1999	81.8	3.6	2000	58.4	2.4	1.1	1999	30.6	1.3
France	2000	177.9	7.5	2000	100.7	4.2	2.3	2000	23.3	1.0
Germany[3]	1999	195.4	8.3	1999	168.7	7.2	3.6	2000	28.0	1.1
Greece	. .	. .	. .	1999	14.3	1.0	0.9	. .	. .	. .
Iceland	. .	. .	. .	2000	17.2	0.6	0.5	. .	. .	. .
Ireland	1998	73.6	3.1	1998	58.7	2.5	1.7	1998	14.9	0.6
Italy[3]	. .	. .	. .	1996	3.2	0.2	0.0	1997	6.3	0.3
Luxembourg	. .	. .	. .	1997	96.8	2.7	1.6	. .	. .	. .
Netherlands	1998	144.3	5.9	1998	113.5	4.7	2.0	1998	26.6	1.1
Norway[3]	. .	. .	. .	2000	81.2	2.8	1.3	. .	. .	. .
Poland[3]	2000	62.7	6.8	2000	42.0	4.5	3.7	2000	20.3	2.2
Portugal	1998	58.5	3.7	2000	40.0	2.3	1.7	2000	14.9	0.9
Slovak Republic	. .	. .	. .	1994	38.3	4.9	3.6	. .	. .	. .
Spain	. .	. .	. .	1999	46.4	2.5	2.0	. .	. .	. .
Sweden[3]	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Switzerland[3]	. .	. .	. .	1999	131.6	4.8	2.6	. .	. .	. .
Turkey	1997	10.5	1.7	1997	8.7	1.4	1.2	1997	1.8	0.3
United Kingdom	2000	17.7	0.7	2000	4.7	0.2	0.0	2000	13.0	0.5

1. Public and business sectors and specialised producers of environmental services (not households).
2. Including public specialised producers of environmental services
3. Per capita: in USD per person at current purchasing power parities – ‰ GDP: per 1 000 units of GDP.

Source: OECD.

Other reported figures for wastewater for example are for the Netherlands 0.6% of GDP and for France 0.8% of GDP (IWA, 2005). The derived figure of expenditure for India is similar to that of high-income countries at 0.71%, though this appears to be somewhat low. The reported figure for China is 1.4%, compared with the Five Year Plan estimate of 1.5%.

Summary

Based on the evidence cited above, the levels of expenditure on water services for high income countries should be of the order of 0.75% of GDP. The estimations for the EECCA countries would appear to show some broad correlation with the empirical work, although the spread is wide (0.3-6%). The evidence suggests that in the case of low-income countries there will have to be substantial increases in the levels of investment if appropriate levels of water services are to be provided. It is difficult to be definitive given the gaps in data and the uncertainties surrounding the available information. Nonetheless, the following ranges of annual expenditures on water services are proposed, covering capital investment in infrastructure and operational expenditures on water resource development, transmission, treatment, distribution, wastewater collection, wastewater treatment and disposal:

High-income countries 0.35% to 1.20% of GDP

Based on a lower bound (Italy) and an upper bound (France) and including figures from Austria, Belgium, Canada, Denmark, Finland, Germany, Netherlands, Portugal, the United Kingdom and the United States.

Middle-income countries 0.54% to 2.60% of GDP

Based on a lower bound (Slovakia) and an upper bound (Georgia) and including figures from Armenia, Azerbaijan, Belarus, Brazil, China, Hungary, Kazakhstan, Poland, Russia, Turkmenistan, and Ukraine.

Low-income countries 0.70% to 6.30% of GDP

Based on a lower bound (India) and an upper bound (Uzbekistan) and including Moldova, Kyrgyzstan and Tajikistan.

4. Key factors driving future demand and infrastructure investment requirements

Background

A set of common trends and eight key drivers that are expected to impact on infrastructure provision in general have been identified and discussed in broad terms in the trends report (Andrieu, 2005). This section considers the significance of each of the eight in terms of their influence on the requirements for and provision of water services. Only the aspects of the drivers that appear to be of a more immediate relevance are examined within the 2025 time scale.

Geopolitics

Non-state actors

As inter-state relationships have become more complex, states have increasingly sought to establish international mechanisms to facilitate and mediate those relationships. In certain areas this has resulted in the assigning of policy and actions to international bodies outside the control of any one state. The European Union (EU) is perhaps the best exemplar of this. The EU plays a particularly important role in the European water sector as it is instrumental in setting standards and requirements that have a significant impact on the required water services and infrastructure to meet these. There has also been a complementary process of devolving responsibility for a range of water service functions away from central government to either local or regional bodies or delegating to state or non-state agencies. This process is the "hollowing out" of the nation state (Jessop, 1995).

The terms of international trade and matters such as subsidies and access to the provision of services and markets are also increasingly being regulated internationally. Such moves will contribute to the further embedment of globalisation and the buttressing of the role of non-state actors, such as trans-national and multinational corporations, which are better able to mobilise access to resources and to project themselves on a global scale in their areas of expertise. This has been under way in the water sector for some time, with a small number of North American and European utility corporations taking on increasing responsibility for the provision of water services across the globe. Paradoxically, these globalising trends are also likely to lead to a rise in locally based initiatives such as partnerships or local affiliates that reflect and capitalise on local circumstances in order to minimise risk.

Both trends are likely to have a significant influence on meeting the demand for and the control and financing of water infrastructure services. An important factor will be the degree to which national governments or agencies will have the ability, power and expertise to exercise oversight of non-state actors.

Scarcity and conflict

Earlier this report highlighted the problems of access to water. According to Alcamo *et al.* (2000), the population living in water-stressed areas could double over the period 1995-2025. By 2030, two-thirds of the world's population may experience moderate to high water stress, mainly in the least developed regions where there is a lack of physical and institutional infrastructure capable of mitigating the impacts. It is the regions of the Middle East, North Africa, Southern Africa, South Asia and China that will be of particular concern, although stress also seems to be increasing elsewhere in countries such as Australia. Forced migration due to water shortages has begun in China, and India could be next (ACNU, 2004). By contrast, wealthier countries will be better able to cope and respond to these challenges through a range of adaptive measures, such as technological solutions, better demand management and long-term planning.

Water scarcity and competition has the potential to create international conflict where there are overlapping national boundaries. Some 40% of the world's population live in the 250 major river basins shared by more than one country. In Africa one-third of all water flows through the Congo, while only a tenth of the population lives within its basin. Economic development in Sudan and Ethiopia will draw on the Nile's waters, making the potential for conflict with adjacent states a real concern. Notwithstanding a number of established international mechanisms for mediating the problems of shared water resources, there is ongoing potential for water-related problems to contribute to regional tensions, such as in the Middle East (surface water resources) and Palestine (groundwater), and these may be exacerbated due to climate change.

Oil and gas resources are of major significance for water services as technologies used for each stage of the process in the main rely on energy and transport. Increasing use of desalination is particularly vulnerable to energy shortages. Security of supply of energy may become problematic with competition in the Middle East. This risk may support both an aggressive approach to maintaining access to energy sources and also new approaches to treating water. Other important resources influencing water services include anticipated shortages of readily available mineral potassium, predicted by some to be exhausted within 50-100 years. This is prompting initiatives for recovery from sewage (Tjandraatmadja *et al.*, 2005) and may require concerted international action.

Evaluation

Both these factors are likely to be of importance in creating and meeting the demand for infrastructure. They will be instrumental in bringing about greater efforts on strategic grounds to develop international institutional agreements in order to reduce tensions and share responsibilities and resources. However, they are unlikely to be primary but rather to be contributory drivers.

Security

General

Threats to security in general appear to be increasing in tandem with globalisation and enhanced communication. Security of water infrastructure has been recognised by governments worldwide and is a major consideration in the United States where new investments have been made and a range of new institutions set up to deal with this and other threats (Copeland and Cody, 2005). Since 2002 for instance, publicly available evidence suggests that the US Congress has provided USD 608 million for studies and passed legislation for vulnerability assessments. This is likely to be an underestimate of actual spend. Threats include physical disruption, bioterrorism/chemical contamination and cyber

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attack. However, for there to be any serious threat to the infrastructure itself it would have to be credible, widespread and sustained in its potential effects, and this would require massive doses of poisons or biological agents. Responses to any threats should ultimately be incorporated in existing contingency plans to deal with emergencies arising from natural phenomena. A few very large plants located in urban areas in the United States supply some 75% of the population, and any attack on these could have major implications. Locally the smaller plants are more vulnerable as security measures are lower, but any consequences of attacks on these would be less widespread. Water infrastructure interdependence on other services, such as ICT, also makes it vulnerable, although there is considerable knowledge following the preparations for Y2K that should help mitigate problems. Nevertheless it is more likely that widespread disruption would be effected more easily via cyber attack, disrupting power, communication and control systems. The effects can be demonstrated by the power failure in northeast United States in August 2003, in which a number of wastewater treatment plants failed. That led to environmental pollution and households being advised to boil water due to failure of water treatment plants (Copeland and Cody, 2005). New technologies are emerging for better collection, analysis and use of information related to infrastructure and asset performance, and as this becomes more sophisticated it may also become more vulnerable to security threats. Instrumentation for water service systems has not been as reliable or effective as in many other areas, and terrorist threats could well encourage more investment in the development of effective instrumentation for water infrastructure monitoring and control. The development of novel technologies that are less vulnerable also may well be forthcoming.

Other potential consequences arise from threats to maintaining adequate functioning of water infrastructure, due to the inability to finance the services provided, unavailability of the necessary expertise, goods and services, and the inability to provide service to meet the legitimate needs of citizens. Threats to functioning could arise from social unrest and inequality, as exemplified during the apartheid era in South African townships; from environmental factors due to climate change; from economic factors that cause affordability problems; or from overloading of systems that results in scarcity and excessive unauthorised and uncontrolled expropriation of supplies.

Evaluation

Security considerations are moving up the agenda and are likely to be aided by the introduction of new technologies and more robust designs, following considerable investment if these are included as part of military perspectives. Organisational security, however, is dependent upon socio-demographic, cultural and economic considerations, and as such is considered to be a manifestation of the consequences of other drivers.

Macroeconomy

Output growth

Although income per capita will increase, its distribution across countries will be uneven and likely to become more so. Developing countries will face large and persistent income gaps, and the poorest in other countries may become increasingly marginalised. The World Bank has anticipated that the economic gap between developing and developed countries will close as a result of a faster growth in income in the developing countries. This should translate into a proportionately greater ability to pay for water services. However, sub-Saharan Africa is expected to fall behind as its per capita income growth will lag behind, lessening even further its ability to fund water services. Linked with climate change, increasing desertification and droughts, this may provoke massive migration and abandonment of previously inhabited lands.

Globalisation and location of economic activity

Globalisation as characterised by the increase in trade and capital movements has the potential to be a significant driver for water services, both in developed and developing countries. In developing countries the growth of manufacturing, reflecting rapid industrialisation, will accelerate with a corresponding rise in the demand for infrastructure services to support this growth. Tourism will also continue to place additional and seasonally varying demands on the water infrastructure in some developing countries. At the same time in developed countries, the relative scarcity of and competition for resources (increasing due to climate change) will provide the impetus to reduce reliance in some areas, of which water could well be one.

It is expected that India and China will become major economic powers after 2015. This is underpinned by their growth in prosperity, commitment to education and stable government. Both the United States and European Union will continue to be major players in international capital and influence, and all OECD countries will continue to grow economically.

Economic structure

It is expected that in most developed countries the labour force will be urbanised, and will either stagnate or shrink due to increasing use of automation. Employment in both agriculture and manufacturing will decline further, adding to the urbanised nature of these societies and their expectations, although in China and India the recent growth in agriculture as part of the economy and reliance on irrigation may continue. Hence in these and a number of other developing countries, although there will be rapid urbanisation and a concentration of economic activity in the cities, agriculture will remain a significant employer and part of the economy. These will also be the areas of the

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highest growth in the labour force. Such changes will underpin the demands for water services and control the types of service to be provided, especially in the urban areas.

Public finance, investment and capital markets

Public finance and privatisation

In most OECD countries, not only will total tax revenue become harder to raise, but the demands on public spending will increase. This situation will leave less room for discretionary expenditure by developed countries, either on "bail-outs" in their own countries or on direct aid to developing countries.

Privatisation has been seen as an important reform measure enabling improvements to be made to service delivery, especially in the field of infrastructure provision. Shifting the burden of funding from the public to the private sector is regarded as the way forward, especially in public utilities; it is only reasonable to expect this process to continue as a popular option for policy makers. On the face of it the water sector should be an attractive prospect. It is an essential service; it is technologically relatively low risk, and if reasonably well managed offers steady though not spectacular returns. However, some recent examples of problems with the involvement of the private sector from South America, South Africa and the Philippines sound a note of caution, as does a growing reluctance in Europe and Australia to adopt outright the "British Model" of privatisation.

The involvement of the private sector in the public provision of services such as water is likely to grow in importance, especially given the huge engineering and financial challenges to be faced in the provision of new infrastructure and the maintaining of existing assets. The nature of the relationship between the public and the private sector in this regard will have to evolve from the present models in order to gain greater political and social acceptance, especially in developing countries.

Investment

With private capital flows likely to be increasingly directed towards the fast-growing developing countries, some are likely to be targeted at financing the necessary infrastructure required to underpin economic growth. In contrast, those countries and areas that are perceived as being insecure for whatever reason are unlikely to attract significant foreign direct investment (FDI) – although the lessons from the history of FDI in the 19th and 20th centuries does demonstrate that investors appear to be an inveterately optimistic breed. This situation creates opportunities for companies capable of tapping into these capital flows to create and invest in infrastructure and services in the more attractive and strategically targeted developing countries.

These may well offer better prospects of returns than the developed OECD countries with their tighter sets of controls, regulations and expertise. It is likely though that the majority of TNC/MNCs specialising in the utilities sector will continue to expand their activities across a mix of countries as a way of spreading risk and exposure.

The growing disparity between tax income and the demand for public services will severely challenge the ability of governments to finance infrastructure out of public funds, and will add to the pressure for greater involvement of the private sector. Thus there will likely be increasing participation by the private sector in the provision, financing, operation and maintenance of water services. In those developing countries with weak governance and oversight capabilities it is likely that TNC/MNC will act increasingly independently as a way of offsetting risk, while in rapidly developing countries the relationships will become increasingly aligned to the models adopted in the developed and OECD-centred countries.

Demography

Population growth and urbanisation

While the world growth in population will continue, that of the developed countries and especially in the OECD, where currently growth rates are around 0.5%, may decline after 2030. The age composition will also change; people will survive longer as health and living conditions continue to improve, with the median age increasing from approximately 38 to 45 by 2030. The implication is that a greater percentage of the population will not be economically active and hence will be more reliant on the services of those who are economically active. In addition, there will be increasing reliance on PCPPs (personal care and pharmaceutical products) that include a wide range of complex synthetic substances that may be persistent, accumulative and toxic if these enter environmental systems via toilet flushing (Kolpin *et al.*, 2002). These and other xenobiotics may impact so significantly on rivers in developed countries that new and more advanced wastewater treatment systems will need to be installed. However, on the positive side, the older population may have more wealth which conceivably could be invested in utilities. By contrast the developing world's population will continue to increase significantly but at a declining rate that is not expected to peak until after 2050. Six countries are expected to account for at least half of the projected increase: the Indian sub-continent of India, Pakistan, Bangladesh; then China, Nigeria and Indonesia. Although the median age in developing countries is likely to increase, it is still substantially lower than in the developed countries; currently it is around 25 and will rise to 33 by 2030. The implication is that this will create a substantial increase in the numbers of the economically active workforce.

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Almost all the population growth in developing countries will be accounted for by urban growth – as was much the case in Europe in the 19th century during its period of industrialisation. Urban growth will be driven by inward migration from rural areas as agriculture becomes more commercialised and there is less scope for family-based subsistence agriculture. This migration will be attracted by jobs and services in urban areas, and there will also be increases in the local urban population from those already living there. The rapid population growth in developing countries in the urban areas, coupled with the pressures of economic growth, will give rise to considerable demands for water services both to provide industry with a base resource and also for the survival of the population. Given the low level of income of the majority of the population, the challenge will be to provide and extend a basic level of service to the burgeoning population centres at an affordable cost to both government and citizens alike. In the developed world, given that overall population figures will be stable, the challenges are more likely to arise as a result of the consequences of the ageing population rather than the need for new water services. Indeed the rising expectations and relative wealth of the ageing populations may well result in calls for higher levels and different forms of service from the existing infrastructure.

Environment

Climate change

A recent report expected that "climate change will have a major impact on water resources in Europe that in turn may require changes in the way that Europeans manage and protect these resources". Drought risks will increase in Central and Southern Europe (Eisenreich, 2005). Globally, water vapour and precipitation are expected to increase, particularly at the higher latitudes all year round. In tropical zones it will increase, but not in subtropical regions. However, there will be an increase in potential evaporation that will generally decrease soil moisture. Nonetheless there will be bigger demands on groundwater and the greatest impact will be on agricultural practices. The extent of climate change and its impacts on the human and natural world will depend on the mitigation measures adopted and the adaptations made. However, given the likely increase in demand for energy and that increase continuing to be met from conventional sources, the consensus is that climate change is likely to become increasingly important. Although varying globally, it is expected that – in addition to the above – it will also contribute to a rise in global temperatures, and thus to major sea level rises and other impacts on the global weather system. As a result climates will become increasingly more erratic, with more droughts and floods affecting the more vulnerable. Food supplies may need to be adapted to use less irrigation water and land use may need to alter where low-lying lands, such as much of Bangladesh, become uninhabitable. As yet, however, the effects on water systems are very uncertain (Bolwidt, 2005; Eisenreich, 2005).

Pollution

The rapid urbanisation in the developing world, coupled with a substantial rise in economic activity and industrialisation, contributes to increasing levels of pollution in the developing world, and inevitably will continue to do so. Measures to address pollution in these areas and their effectiveness will generally lag behind in terms of priority for these governments despite agreements to international control protocols. Increases in population and economic activity will place further demands on natural resources and their exploitation, also giving rise to pollution. As agriculture becomes more commercialised it is likely that there will be an increase in the use of chemical and biological products to both increase production and prevent (short-term) damage, also contributing to pollution. These trends pose very serious threats to the integrity of water resources, although they will be preferable for human health and welfare.

By contrast, growing public concerns, tighter regulations and the implementation of pollution abatement measures in the developed and some parts of the developing world could bring about substantial improvements in the quality of the environment and decreasing absolute levels of pollution. However, there will be an increasing number and complexity of pollutants as new products and processes are developed.

Evaluation

It is likely that the challenges arising from the environment are going to be substantial. While pollution abatement in developed countries has been successful in arresting decline it has added substantially to the costs of providing the appropriate level of water services. This is now possibly the greatest single driver, particularly in the EU. The full economic cost of these measures is not generally borne by the customer and as fiscal demands on governments increase these will have to be passed on to customers. In the developing world the emphasis is likely to be on the provision of infrastructure to meet basic needs with expensive pollution abatement measures necessarily foregone, although with certain technologies this may be better controlled. Thus there will be a need to develop cheap, cost-effective means of reducing pollution in parallel with appropriate technologies.

Climate change presents some very severe challenges. Not only will the security and certainty of water resources decline but their vulnerability will increase as well. Added to this is the likelihood that infrastructure itself will be increasingly vulnerable to damage arising from sea level rise and flooding, storm damage, flash floods and the accentuation of seasonal effects such as winter flooding and summer droughts. All these pose major challenges to the robustness and resilience of water services and will place increasing numbers of people at risk. In agriculture, effective irrigation will be an essential goal. This should be accompanied by changes in the crops being produced in water-stressed areas, in order to minimise the need for the exploitation of new resources; the latter are in any case unlikely to be readily available at a price that agriculture can afford if it bears the economic cost of water services (*e.g.* Vecino and Martin, 2004).

Technology

Technology as a potential driver plays very much a supporting role in that it can make the existing infrastructure more efficient and at the same time lower the cost at which services could be provided. Water services technology will not be able to change the physical facts that water is heavy, ephemeral in nature and expensive and difficult to transport and store. What it can do is impact on the "soft" infrastructure constituting the service component that transforms water from a raw material into an economically important good.

Currently the main perspectives here relate to the inertia of the "traditional" technologies, the application of these from the developed to the developing world, and the movement to utilise more sustainable approaches in the latter. It is still apparent that the large suppliers of water services globally, together with the funders, favour the traditional approaches, perhaps with some new technological components such as membrane filters for the larger conurbations. Aid agencies meanwhile tend to promote ecosanitation and small-scale, easily maintained technology. Reconciling these approaches is the subject of ongoing research and depends on the drivers and urgent imperatives (*e.g.* CSIRO, 2005). For example, desalination technologies are perceived to be appropriate for new breakthroughs using advanced membrane technologies and offering greater energy efficiency. However, water will still need to be transported from coastlines or from areas of brackish water sources to the users.

Water service providers are having to be more innovative and are exploring alternative or new technologies and asset management techniques that can improve their knowledge and understanding of water supply system operation and management, and help deliver these more efficiently. Changes in current practice are required that entail greater use of information and increasing automation while ensuring that human operatives can make decisions about system changes in a "smarter" way. Advances in information technology and communications in other sectors, coupled with space technologies such as earth observation, will revolutionise their everyday use within the water sector, especially as the costs of the acquisition and use of these technologies drop. This could lead to a much greater ability to monitor all aspects associated with service provision, the circumstance and the events surrounding it, in greater detail and to a greater extent than is currently technically possible. However, this has to be coupled with the ability to control and make better use of water and the service infrastructure by being able to communicate in real time between sensors, databases and intelligent system modelling technologies. This would enable supply infrastructure to respond intelligently to changing circumstances as and even before they occur. The increase in computing power at all levels of application will be a key factor in enabling the development of cyber modelling and control. What is done for the water supply infrastructure as it transports water from source to point of demand can also be applied to other areas of activity such as industry, buildings, the home, and in agriculture, where online sensors can be used to balance water needs for irrigation with supplies, getting round practices such as flood irrigation. However, costs and ability to operate these systems will be constrained in developing countries, which is mostly where the biggest users operate.

Biotechnology will have the greatest impact in the areas of pollution prevention, monitoring and remediation. It has the potential to completely revolutionise water treatment processes and may well enable service providers to dispense with conventional treatment plants as they are known today. Much of the treatment would not require a large capital investment for the provision of large fixed infrastructure, as this would be replaced by in-system and on-site processes, tailored to specific circumstances and requirements. It could even lead to the elimination of the distinction between water distribution and sewage systems as it becomes possible to combine them without impacting on public health. In the same way the associated costs and energy consumption would drop considerably, thus substantially reducing the cost of water services. It may be possible to incorporate and deliver bioengineered health products. Bioengineered organisms might be used to recover resources and to produce new sources of energy, raising the possibility that water service providers would also be major energy producers. The application of biotechnology to crops and plants could lead to the emergence of drought-resistant strains, which in turn would reduce the overall demand for water.

In the field of nanotechnology, advances are likely to have the greatest impact on maintaining and enhancing infrastructure performance. This could come about through the use of sensors, smart materials and materials with the ability to self-heal and regenerate. Coupled with ITC advances it could usher in an era of autonomous operation of water service infrastructure (robotics) where the need for human intervention in areas such as dealing with deterioration or breakage would be all but eliminated. The skills mix required would change substantially and could lead to a significant increase in productivity and reduction in the size of the workforce required to operate and maintain systems and infrastructure, also reducing costs.

While much of this could be achieved in developed countries with the necessary resources, it is less certain if the same sort of approaches could be implemented in developing countries. In those with rapidly developing economies that attract substantial FDI, a similar model could well be applied. However, it is unlikely that other developing countries without the skilled resource base will benefit or be able to realise the scale of cost reductions that such technologies could bring. Overall the technological advances would almost certainly bring about the virtual closing of the water cycle in the areas of domestic and industrial use, leading to a potential decrease in the demand on new resources. In agriculture the efficiency of per unit water use would increase substantially through the ability to target and tailor the application of water coupled with an improvement in crop strains.

Public decision making

In both the developed and developing world, decision making is and will become more complex and problematic but for differing reasons, such as the rise in power and influence of some stakeholder groups, particularly the MNIs. This will affect key issues such as how infrastructure will be financed and its location, with nimbyism becoming more prevalent in the developed countries. Ironically, public access to information and measures such as those deriving from the Aarhus Convention in Europe actually may not facilitate access to information about how decisions are really made, due to commercial confidentiality. In the developing world the pattern of decision making will continue to exhibit wide divergence, correlated with economic development and performance and the rise of a middle class. This will determine the role of the private sector, although it is likely that many developing states will seek to maintain some form of control over the provision of water services. Thus partnerships, franchises and concessions could well be the preferred mechanisms for engaging with the private sector, including both local and MNC/TNC. There will be mechanisms for incorporating degrees of local involvement of communities and of accountabilities, but the essential relationships will remain at government level. In the case of those lesser developed countries (LDCs) with poor economic prospects it is anticipated that the role of the private sector in water services will be relatively weak and conversely that of international non-governmental organisations (INGOs) correspondingly important as they enter into partnerships with local bodies, effectively bypassing government in order to provide services to the poor.

In the developed countries the hollowing out of the state will lead to a divergence of modes of decision making. Supranational bodies, such as the EU and WTO, will become increasingly important with respect to policy issues and the terms of engagement. At this level decision making will involve state as well as non-state actors representing a whole range of interest groupings, with business interests having a powerful voice. Below the level of the nation state there is likely to be a greater role for non-state actors such as businesses in the provision of water services but subject to increasing levels of regulation imposed from the supranational arena and overseen by state-sponsored agencies. The greater availability of information and of ITC to citizens will increase their ability and opportunities to become interactive in the field of service provision. Thus new ways of involving citizens in decision making both in the public and private sectors will grow in importance. This will be underpinned by a growth in the rights of individuals as well as the increase in demand-driven schemes where users of a service pay the full economic cost of the provision and maintenance of that service. This implies that localised decision making will become more prevalent as well as easier. It does, however, suggest that decisions regarding regional issues may become more problematic and that large and costly public inquiries may delay investment in major infrastructure where this is proposed.

5. Impact of key drivers on future levels of infrastructure investment

Introduction

The purpose of this section is to explore the likely impact of selected drivers on the future demand for infrastructure and the consequent implications for investment. In order to do so the situations outlined in Sections 2 and 3 are taken as providing a baseline against which the possible impacts are judged. Potential future drivers that would have an impact on the demand for and configuration of future water services have been outlined in Section 4. Only the most important of these are considered below.

Geopolitics

Beyond the Nation State

There are already a number of trans-national organisations that exert varying degrees of influence over the provision of water services at the level of the state and below, such as the World Bank and its affiliates, the WTO, UN bodies, INGOs, the EU and, to a lesser but potentially increasingly important extent, TNCs and/or MNCs (multinational corporations). Of these, the WTO and EU stand out in their ability to set standards, require compliance, take forms of legal action and impose penalties for breaches. Globally it has become apparent that as trade negotiations and frameworks have developed, there has been a greater sensitivity to domestic regulations that relate, among other things, to environmental matters (Oye, 2005). There is a growing potential for conflict due to both increasing trade sensitivity to regulatory difference and increasing uncertainty about the environmental risks being regulated. This is exemplified by regulations that actually advance parochial interests while claiming to target holistic environmental and health protection. In this respect there are perceptions that the stance taken by Europe and that taken by the United States are at odds (Oye, 2005).

The EU exerts an "arm's length" and overarching influence on water services, not just in the member and accession states but also in countries such as Turkey, Russia and other EECCA states that seek closer economic and political ties as well as trade suppliers from around the world. It is in the area of environmental protection and pollution control that the influence on water services is most marked. The raft of directives includes: Drinking Water, Bathing Waters, Wastewater Treatment, Habitats and more recently the Water Framework Directive. All of these had and continue to have a significant impact on the requirements for and provision of infrastructure to meet their conditions. They have also had an impact on the way services are provided and on operation and maintenance activities. The directives have been instrumental in the re-evaluation of the institutional and organisational structures of water service delivery at the level of the state and local levels and have opened up the industry to greater and varying forms of private sector involvement. Meeting directive requirements, given the backlog of past problems and the scale of their objectives, will continue to be a driver for investment in new infrastructure (*e.g.* Mohajeri *et al.,* 2003). In the United Kingdom some 30% of investments are connected with environmental and quality drivers – approximately 0.25% of GDP; in some countries, given the catch-up required, it could be more.

Other regions of the world have aspired to emulate the European model in one form or another, although none has come to a similar degree of co-operation.

The impact on infrastructure of the WTO is perhaps more indirect; it tends to be concerned with the terms and openness of trade and services, although of relevance are "dispute settlement panels" that attempt to resolve domestic environmental regulatory problems (Oye, 2005). WTO's main role will probably be to encourage greater participation of the private sector and especially TNC/MNC in the provision of water services. As such it would influence the sources, availability and terms of financing of operating and capital expenditures. However, WTO has influenced behaviour by, for example, ruling against provisions in the US clean air act and sea turtle protection, and also against EU, Australian and Japanese environmental regulations, mostly on the grounds that these were disguised trade barriers. The approach is precautionary, which can be extremely stringent without very much proof of consequence and can lead to irreversible and expensive decisions and regulation. This precautionary principle is justification for the forthcoming EU's prescribed substances daughter directive to the Water Framework Directive (WFD) that seems to impose absolute and unreachable standards for prohibiting discharges of certain substances in wastewater, despite environmental background levels being much higher. The consequences of this will be to force EU countries to invest huge sums in wastewater treatment.

The above illustrates that greater participation of international bodies could impact on design, development and other areas that indirectly affect operation and provision of infrastructure. Standards, benchmarking and technology, for example, could have either detrimental or beneficial effects on efficiencies, thus increasing or reducing costs and affecting levels of affordability.

The impacts of moving beyond the nation state will be felt not only in the developed world and OECD countries but also in the transition economies of East and South Asia and Latin America. Impacts are less likely in the low-income, lesser developed countries of Africa, where the challenges are more localised and closely linked with coverage, access and keeping up with basic water service provision.

Water and other resources

The population living in water-stressed areas is set to double over the period 1995-2025, and by 2030 two-thirds of the world's population may experience moderate to high water stress (Alcamo *et al.*, 2000). Regions of particular concern will be the Middle East, North Africa, Southern Africa, South Asia and parts of China. Some countries are already ill-equipped to meet this challenge; as noted above, China's reservoir storage is low in comparison with other countries and India is probably in a similar position. Many of the megacities of tomorrow are located in areas notable for their scarcity of water resources. It is axiomatic that the problem will be most severe in the least developed regions, where there is a lack of physical and institutional infrastructure capable of mitigating the impacts. The most likely response would be to seek to invest in harnessing additional water resources through reservoirs and transfer schemes, such as the Three Gorges and South-to-North projects in China. Such trends have been apparent in Africa. It is often perceived to be easier to address the problems of scarcity through supply-side measures rather than by alternative means of demand management. Thus in transition and developing economies water scarcity will likely prompt interest in new works to harness further water resources. The costs of such projects will continue to escalate, raising questions about their economic viability when compared with other alternatives. Water scarcity may provide the necessary impetus to develop and strengthen institutional means of governing and guiding water resource development at international or river basin level, the development of property rights, and markets in water rights and allocations. This could mitigate the expected pressures for new resources. The losers in all this would be rural water services and agriculture, especially irrigated agriculture, unless there is a strengthening of local rights, possibly through the expansion of Water User Associations (WUA) as advocated by international agencies.

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The availability of water resources could become a factor influencing the location of centres of industrial and manufacturing activity as these industries are relocated to transition and developing economies.

In the case of many of the developed economies it is not the scarcity of water resources that will be the problem, as generally water stress will lessen. The balancing out of availability would need to be addressed, and this is linked to predictions of the impact of climate change on resource availability patterns. The rising standards of environmental protection and other factors will drive up energy demands, and it could well be that energy will become a limiting factor in making resources available.

Security

There are increasing concerns over security and terrorism in some countries, notably the United States. That country has already invested considerable sums of money researching the issue and has made budgetary provision to "harden" its water infrastructure against acts of terrorism and sabotage: USD 1.2 billion (EPA, 2005). It is noteworthy that this is less than 10% of the amount allocated to deal with the presence of lead piping in distribution systems. Concerns over vulnerability of water services infrastructure worldwide are likely to result in protection efforts in only a limited number of states that can afford to increase the robustness of their systems, such as the OECD member countries.

Of greater potential influence is the security of electrical and electronic infrastructure that supports the operation of water services. The operation of water and wastewater systems relies on electricity to be able to function. Recent events in the United States have served to underline both the vulnerability and consequences of any failure of the electrical system or even shortages. It is an emerging area of concern, and at this stage the impacts are not well understood. Potentially it could drive new developments and demand for technology in decentralising schemes, and add additional system redundancy in order to increase resilience. It would also spur investment to utilise the embedded energy in water and wastewater as well as advances in new ways of pollution control as a way of reducing operational costs in the long term. As well as recovering energy at sources such as reservoirs and other storage sites, possibilities include turbines in water transmission and distribution systems and in sewers, and energy from solid residuals from treatment processes. There are now several operational examples of the first of these and the latter has been common for sludge from activated sludge plants for decades, but is still often not utilised due to capital and running cost fears.

In a similar way that concerns over Y2K led to developments in software and electronic systems, so threats of terrorism and cyber crime would lead to investment in improving the robustness of these systems. Such developments would not come specifically from the water sector; rather, the sector could draw on the advances made in other business areas, especially with respect to communications, databases and control systems.

In terms of the possible impact on funding and investment it is expected that much of the cost would be absorbed within existing budgets and would not give rise to additional programmes of work requiring special funding streams, although it may facilitate access to military spending sources. These developments could be widely adopted across all but basic service provision, such as for rural water services.

Macroeconomy

Economic growth

World income will continue to grow, rising by 3.1% p.a. to USD 51 800 billion in 2015, with world per capita income also rising but significantly faster than in the past three decades (World Bank, 2005). Also, the income gap between developed and developing countries should shrink given the differences in their rates of growth, with the fastest growth taking place in East and South Asia. This continued economic growth will require substantial upgrading of infrastructure if the development is to be supported. New infrastructure development would mostly take place outside of the OECD countries, while within those countries water systems and services would require maintenance and upgrading in response to the changing structure of economies and increasing societal requirements. The ability to fund and therefore provide water services does depend on continued economic growth. The figures have shown that as an economy develops, the composition of its economic stock and the relative allocation of sectoral investment changes. In these terms, water services decline in importance relative to other infrastructure stocks and proportionally require less investment. Thus as economies grow, the burden of investment decreases and affordability increases – in other words, the whole system becomes more affordable. It also implies that financial investment in water service providers becomes less risky, that stock market performance is less volatile, and that returns are steady and stable but not spectacular. Thus, continued economic growth in developing countries provides one of the means to improve their water service provision and to cope with the increasing demands, especially in the rapidly urbanising areas. The funding gap that is apparent in some countries (WaterAid, 2005) could gradually be addressed.

A slowdown in economic growth would have a severe impact on the ability of countries to invest in and maintain their water services and lead to a widening of the funding gap even in more developed countries. An indication of the consequences could be gained by reference to the experiences of Russia

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and the former Eastern Bloc countries in the late 1980s and through the 1990s. Investment in new works would be severely curtailed, the required levels of maintenance would not be achieved and regulatory control would be weakened with poor standards prevailing. Service levels and the financial viability of the service providers would decline, leading to increased levels of customer dissatisfaction and localised improvisation as a means to overcome shortcomings. Health concerns and environmental pollution levels would increase. The cost to the economies, on the basis of previous studies, could amount to 3% of GDP or more. There could be increased pressure from some economic sectors for continuing subsidies, for example in agriculture, as these perform a social as well as economic function. Other effects could be the loss of intellectual capital and curtailing of investment in research and development. On a macro scale there could be a limiting of the international communities' ability to provide FDI as well as donor assistance to developing countries, further weakening their position and ability to extend water services provision. The attainment of the MDG for many countries would be considerably postponed. In OECD countries the impact of a slowdown would be less marked but economic difficulties could in Europe prompt a re-examination of environmental and other legislation that would be perceived to be adding considerable costs without the necessary concomitant benefits. This would have a direct effect on the provision and operation of water infrastructure.

Globalisation and changes in economic structure

Globalisation, together with changes in economic structure, will drive the relocation of industrial and manufacturing activity, which in turn will impact on demand patterns. The industrialisation of the developing world will result in increased levels of water demand and consumption, partly as a result of increased activity and partly as a result of a decrease in water productivity. At the same time developed economies will become more service and amenity oriented, placing a higher value on water and so dampening consumptive use. This will reinforce the requirements for increased expansion of water resources and the associated infrastructure in developing countries while in developed countries the need will be to maintain and improve existing systems. As part of the relocation of economic activity there could be a reinforcement of trends towards self-supply of water services, either directly or through the transfer of funds. There is an opportunity here for increased private sector involvement to supplement local services, a trend that may well be reinforced by GATS and could represent a growth area for the water TNC/MNCs, especially if they could mobilise the necessary funding and technical expertise. However, for sound practices it would be necessary to establish property rights and robust legal and regulatory institutions. Such trends are starting to emerge in both China and India, where the state has sought to distance itself from service provision and reconfigure as an enabler and overseer of that service provision. It could also be envisaged as a condition of relocation that such enterprises be required to take on forms of responsibility for extending basic infrastructure and services, modifying the former communist model of enterprises embedded within communities.

Public finance and investment

Between 1993 and 2002 World Bank infrastructure investment lending declined by 50%, partly due to a lack of clarity on the roles of the private and public sectors in infrastructure service provision and underinvestment in country-level analysis. At the same time, private sector investment in the water sector, which accounted for less than 10% of total investment, has also declined (Hall, Iobina and de la Motte, 2003) as the private sector has become more risk-averse in relation to the water sector. Through the 1990s national governments accounted for two-thirds of capital investment in the water sector and are likely to remain the major source of such finance. At the same time there is a need to encourage devolution of responsibility away from central government in order to shift financial burdens away from taxpayers to service users. Such moves should facilitate better access to local capital and financial markets. For the foreseeable future, it is likely that the private sector will be a major source of managerial and technical expertise rather than investors, especially in developing countries (OECD, 2004). There is a need to develop mechanisms to allow greater engagement with the private sector as far as financing is concerned. As has been observed, although reform and innovation are needed in financial architecture, there is not likely to be any paradigm shift and different sources of finance will be needed (OECD, 2004).

Demography and urbanisation

It is expected that not only global population but also urbanisation will increase, so that by 2030 some 60% will live in cities (UN, 2004). Almost all of the increase in population in developing countries will be accounted for by urban growth. The scale of the growth will place enormous pressures on local governments to ensure that there is adequate provision of basic services. In developing countries urban growth will be fuelled by migration out of the rural areas. Thus those constituting the new growth are likely to be relatively less skilled and will add to the burgeoning numbers of urban poor. The manner in which these urban poor are accommodated and the form of urbanisation will have a determining influence on whether and how infrastructure services are provided and their access to them. One of the key questions will be the ability and competence of local government to manage the pace and process of urbanisation and the institutional ability to undertake infrastructure service provision and the levels of funding that can be mobilised. Hence the challenge

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is not the numbers or rate of urbanisation but rather rate of growth of institutional ability to manage the processes of urbanisation. The major challenges are affordability and revenue generation, the mobilisation of funds and how they are raised. The solution lies in economic growth that enables the required level of funding to be put in place to create the infrastructure and to enable the people to afford the services provided. Thus service level must be linked to affordability (Komives, Whittington and Wu, 2001) – the poorer the household, the less likely they are to access services. The impact of more rapid urbanisation in itself is not the issue; rather, it is how this relates to economic growth and the redistribution of income across society. More rapid urbanisation with commensurate economic growth could in fact be preferable to slower rates of urbanisation with piecemeal development of accompanying infrastructure.

Urbanisation creates problems of water shortage, related to both quantity and quality, as lack of adequate wastewater collection and treatment leads to environmental pollution and deteriorating water quality, thus affecting availability. High levels of water poverty are often associated with poor health and go together with other problems such as poor housing. Evidence from Brazil and other countries suggests that INGOs can play a key role in working with communities in urban areas to extend water services provision (Novy and Leubolt, 2005; Water Aid, 2005; Media Analytics, 2002). In some instances local government has sought to improve coverage by making it a condition of granting leases or concessions to the private sector. Success, however, has been patchy (Bakker, 2005). In sub-Saharan Africa the impact of urbanisation on water infrastructure is problematic in the absence of substantial donor assistance, given the projected continuing economic weakness (World Bank, 2005).

In the context of the developed economies and the OECD, the impact of urbanisation will be on the form and level of service, as affordability should not be a problem. Urbanisation affects not just new areas but also the existing areas of urban conurbations. As new areas are developed and other areas redeveloped in line with natural building cycles, there will be opportunities to reconfigure not just the water services infrastructure but also the services themselves. Recent trends are moving towards significant demand management at a local and household scale and the introduction of alternative forms of sanitation and localised forms of service provision aimed at closing the water cycle and thus minimising the input of new resources (WSSTP, 2005). This will require changes to some regulatory controls; it would also entail a redistribution of responsibilities and the rise of localised and specialised forms of service provision, but still within a centralised system. Thus there could also be moves towards integrated utility management and not just water utility management.

Environment – climate change

Climate change could have a number of effects. As well as droughts, it is expected to lead to sea level rise with consequent loss of land areas and increased frequency and scale of flooding, with the attendant risks to human activities and life. At the same time climate zones will shift and the climate will become more unstable (Andrieu, 2005).

The effect of sea level rise will be felt in different places. It will lead to a reconsideration of land use and might in some cases lead to abandonment and relocation of populations. Countries like Bangladesh and some island states would be most severely affected. Such major impacts, although some time into the future, will require the development of additional water resources and the associated infrastructure to transmit and distribute water to the relocated populations, as well as to handle the wastewater and its treatment. Experience of redevelopment on this scale is limited and the closest is probably that associated with the development of the Three Gorges project in China. The uncertainty would be how the process is planned for and managed. Based on the Chinese experience initial expenditures could be anything between USD 50 billion and 100 billion.

Sea level rise could also adversely affect groundwater aquifers due to increased risk from saline intrusion, especially if aquifers are being over-exploited. This could prompt the need to switch to alternative sources of water such as desalination, which at present is energy-intensive and relatively expensive.

A shift in climate zones such as grain belts moving northwards and desert areas increasing in size would not just affect agricultural production and practices. It would also have an impact on urban as well as rural populations. Per capita water use is correlated with climate and to some extent increases as the climate becomes warmer. Any systemic increase in per capita water consumption would offset any gains from water demand management and leakage reduction measures. The consequence could be a need either to develop new water resources or to adopt new, more water-efficient technologies. Either way, additional investment would be required.

More unstable and less predictable weather patterns will mean more droughts and more severe and frequent flooding events. One response would be to do nothing; in fact, some countries may have no option but to seek to live with the consequences as they would be constrained by natural and economic conditions in what they can do. Many countries in the Middle East, North Africa, sub-Saharan Africa and Central Asia may find themselves in this position. Water resources will already be developed and additional resources scarce and costly or beyond further development. In these cases there may have to be a reliance on temporary, unsustainable solutions, or humanitarian assistance and disaster relief, or both. These countries' ability to have introduced mitigation measures such as minimising consumptive use will be constrained by their economic situations and the competing demands on scarce financial resources, as well as the nature of their urban and rural settlement patterns. In middle- to high-income countries it should be possible to introduce mitigation measures, as part of the urban redevelopment cycle discussed above. A number of research projects are already addressing the issues of how to reconfigure existing and urban infrastructure as well new infrastructure to address the impacts of climate change. At the same time governments, certainly in Europe and some other OECD countries, have initiatives looking into the impact of climate change, both from an infrastructure and institutional point of view. Climate change in these countries will add to infrastructure costs, some of which will be borne out of general taxation. These are anticipated to be containable within current levels of expenditure on operation of and maintenance on existing infrastructure.

In the agricultural sector, climate change could trigger major changes in water use patterns as crops and cropping patterns respond to new sets of growing conditions. More effective irrigation will be required, prompting investment. In some areas such as Europe, China and India there will have to be a re-evaluation of the role of agriculture in the economy: is it a purely commercial activity or part commercial, part social?

6. Impact of key drivers on the future quality and structure of water-related infrastructure investment

The key drivers likely to impact on the long-term demand for infrastructure in the water sector have been grouped under four broad headings: socioeconomic, technological, environmental and political.

Socioeconomic changes

The way water is managed today is not sustainable; current usages are inefficient and of low perceived value by consumers in most of the developed world (Matsui *et al.*, 2001). The focus needs to be shifted from water as a good to the provision of water as a service. Thus, the emphasis changes from a preoccupation with quantity to considerations of types of use or application and matching quantity and quality with those requirements. For this to happen there will need to be social changes to ensure acceptability and responsibility (SAM, 2004). Current thinking considers water supply, in-house sanitation, water use in agriculture and industry, sewer system, wastewater treatment, and river basin management as parts of an integrated system, although service delivery and regulatory frameworks rarely match this. Thus the integrated overarching system needs to be embedded into the local framework of law and regulation, and into the framework of cultural heritage and concerns. The solution will be the integrated and transparent management of water resources, balancing demand and supply by water saving, increasing reuse and exploiting new marginal sources (WSSTP, 2005; Sommen, 2006). All of these require sociological change as a prerequisite for the adoption of technical innovations.

Globally there is a great deal of diversity in the institutional and organisational forms of water service delivery. Clearly there has been a trend towards the decentralisation of service provision, with central governments gradually delegating operational responsibility downwards, often to the municipal level. The question of the appropriate operational scale is one that depends on context, and there can be no one solution. What is clear is that there is a growing need for effective regulatory oversight however services are provided, and a need for central government to continue to play a strategic role, especially with respect to social, environmental and fiscal policy direction. The potential challenges for regulation are likely to increase as new technology is adopted and organisational forms respond to its deployment. It could well be that responsibilities in the area of service delivery will become blurred, requiring a greater level of governance to protect the public. The interrelationship of different spheres of regulation, safety, economics, quality, environment, consumer protection and perhaps others will become increasingly challenging and complex. The private sector's participation in water services will inevitably grow – and not necessarily as a result of privatisation, as there is only weak evidence that privatisation does actually result in greater investment in water services. Decentralisation and more effective private sector involvement are seen to be the way forward through various forms of outsourcing, as service providers seek to improve efficiencies and adopt technological innovations (Mohajeri *et al.*, 2003). Such factors will have a greater influence on the governance and economics of service provision than any impact of trade liberalisation.

In developing countries such as India and China, there will likely be an increasing trend toward forms of partnerships between local and international enterprises. This would make technological advances more readily available and create bigger, more globalised markets and at the same time localise their application. Important factors in enabling such partnerships to flourish would be the strengthening of property rights, a sound judiciary, legally enforceable contracts, the removal of barriers to the formation of joint enterprises and the formation of local capital markets to provide access to the necessary funds. A key issue in the funding of water services will be full-cost recovery and revenue collection. Only if there is certainty over the income stream can there be adequate planning for and provision of services. Decentralisation of responsibility would imply a similar decentralisation of revenue generation and a lesser level of reliance on central forms of funding. Achieving a balance between central and local forms of revenue generation and its allocation will continue to exercise the minds of policy makers. Technological changes and better ICT will enable there to be more sophisticated forms of revenue raising, tailored to more individual requirements and consumption patterns. This does mean, however, that there will be a great deal more interaction between customers, consumers and service providers in ways that are not immediately apparent today, albeit a lot of this may be "virtual" and there might need to be moves towards individual accounts management.

Many of the changes, whether in the developed or developing world, will depend for success on trust and the management of expectations. In this the role of the service providers but also of stakeholder groups representing ranges of interest will be important. Trust will also be important in respect of how growing forms of social risk are managed and accommodated. These risks would be associated with climate change effects, such as drought and flooding, security of supply, the security of the services and the ability to support economic growth.

Overall, socioeconomic changes are expected to increase unit costs of water service infrastructure delivery into the foreseeable future. This will be due to the following, singly and in combination: population growth; population profile changes; rising unit demand and expectations for water services; more extensive service provision; and increasing use of private sector services with risk costs.

Technological changes

Water infrastructure technology in developed countries exists in its present form in large measure due to strategic decisions made in the past. Hence these systems are "path dependent". Fundamental strategic choices have been made in the past without proper critical evaluation, but dictate paradigms of delivery for long periods (Juuti and Katko, 2005). Current approaches to water supply and sanitation, developed over the past 150 years, are time-consuming to install and expensive, and generate environmental problems such as traffic congestion, dirt and noise. But there is actually no need to rely entirely on these traditional solutions, due to the fact that scientific developments have paved the way for alternatives as effective, reliable and robust as the traditional solutions, but less costly and less time-consuming to install and operate (WSSTP, 2005).

Technological change presents the opportunity to challenge some but not all of the ways in which water services are provided. The key question is the extent to which technology can bring about the closing of the water cycle such that the requirement for the input of new resources is minimised. It must do so in a way that is cost-effective, appropriate for those who must use it, and capable of widespread adoption. There will be technological requirements to enable localised cycles to be closed, and at the same time technological needs to manage the wider systems within which the localised systems are embedded. This may be supported by enhanced techniques for desalination in the near future, benefiting arid countries in particular.

There will be increasing requirements for real-time monitoring and control at every point in the water cycle. For developing countries, small-scale decentralised systems need to be better developed; that will require a range of new technological innovations, including new ICT systems that can ensure the secure operation and continuous monitoring of these systems. Although the systems will be "on-site", technologies for their remote monitoring and control will become feasible. Their uptake will depend on a shift in the perspective of the large operators, from a current "obsession" with large end-of-pipe and centralised systems to this service market.

Intra-local technological needs would include the increasing use of local on-site systems, and better control and management of all forms of water quality at less cost and with greater reliability than at present. This would involve biotechnology applications coupled with ITC and nanotechnologies that can deliver water fit for purpose in context, including reuse and local harvesting in all forms. Moving away from the idea that water is a conveyor of waste is core to the concept. This will require the integration of technologies for monitoring, controlling and removing diffuse and point pollutants; they will need to give timely warning of and react to pathogens and pollutants – at all stages of the water cycle, with ecologically degradable products (sustainable chemistry). They will also need new sensors integrated with new ICT tools to communicate both on-site and between sites. New approaches to dealing with bio-solids for other uses are also required. Overall the new technologies should produce less waste and use fewer resources. Smarter operation of all assets will require the deployment of sensors integrated with robotics to reduce the risks associated with long-lasting below-ground assets failing and optimising interventions. Low maintenance or self-maintaining systems are needed. The operation and maintenance of such systems holds implications for the organisational structure of how such services are delivered, charged for and regulated. However, even in developed countries there would be problems for some sections of the population associated with their economic status and the "digital divide". Thus the introduction of such technologies and placing in the hands of individual consumers greater control over the service provided to them will require careful development and capacity building, as well as access to and choice of alternatives.

While it would be possible to envisage such schemes at the household or small community scale, this might not be appropriate in the context of developing economies or in expanding megacities. It should however be possible to scale up such applications such that larger populations at suburb level could be served as in the "on-site" wastewater treatment systems now being utilised in the United States (USEPA, 2001) and Australia (WSAA, 2005).

There will still be a need for interconnectivity between local systems, akin to the present distribution systems, as well as the resource, distribution and treatment systems, referred to here as inter-local systems. New biotechnologies present the possibility of using what were previously marginal quality waters – *e.g.* brackish, grey and black waters – as potential resources, reducing the demand for new resources. Remote sensing and monitoring technologies with GIS would allow for the micromanagement of nutrients in agriculture, and ecosystems would allow timely response to changes in runoff water quality. Coupled with this, satellite technology and GIS would provide early warning for extreme weather and other conditions, allowing the preparation and implementation of appropriate responses. The operation and maintenance of transmission, distribution and collection systems would also benefit from advances in nano- and biotechnology. Service providers would be presented with the opportunity and ability for in-system treatment, self-monitoring and automated robotic maintenance that optimise interventions, bio-/nanofilm coatings and waste products, along with energy and resource recovery. Where there are large water/wastewater treatment plants these would move from being consumers to producers of energy and resources (residual solids will be used for, *e.g.*, building).

However, placing an increasing reliance on remote and automated systems increases the risks and consequences of failure, as without due regard such systems can be fragile and when they fail, they fail in a catastrophic manner. The deployment of technological innovations on this scale would be dependent on acceptability and society's as well as institutional capacity to handle and live with it. Thus it would not be appropriate in all situations.

Better technologies for monitoring, controlling and removing diffuse and point pollutants – at all stages of the water cycle, with ecologically degradable products (sustainable chemistry) – also need new sensors integrated with new ICT tools. Also required are new approaches for dealing with bio-solids for other uses. Overall there is a need for new technologies that produce less waste and use fewer resources.

Security is a growing concern in some countries, and as support systems become more sophisticated the vulnerability of the infrastructure increases. Technical failure for whatever reason could lead to widespread impacts, pollution, health-related problems and lack of service provision for extended periods of time. While water systems are for the most part robust, they do rely on other services outside of the water service providers' control; electricity, telecommunications, transport, etc. are all vulnerable. Thus it could prove necessary to develop redundant or duplicated infrastructure, physical or otherwise, in order to increase resilience. An increasing dependency on automated systems, controlled at a distance or with their own AI, potentially poses some serious risks; any future installations of this kind might be required to have back-up or fail-safe mechanisms in place much the same way as in nuclear power generation. There may be regulatory requirements put in place for additional monitoring and reactive systems to be developed that are capable of triggering emergency responses similar to the way immune systems work.

Overall, it is expected that technology will help to attenuate the overall increasing costs of water services. This will be due to: new techniques (scientific, sensor and ICT) and better ways of managing information and hence performance, resulting in smarter ways of operating new and current systems; greater energy; and resource efficiency (net surplus). This presupposes continuing investment in R&D at current levels. One slight concern is that with increasing private sector involvement, R&D may become more internalised, possibly constraining major advances in technology. Hence a modest benefit has been assumed in the analysis below.

Environmental changes

Climate change in its impact on weather patterns will have a noticeable impact on water resources, albeit one as yet uknown (Bolwidt, 2005). The greater climate variability and uncertainty will increase the vulnerability of resources across the globe. This will also occur in those countries and regions where there is not expected to be an increase in demand for withdrawals. Two potential but not mutually exclusive responses may be envisaged to increase the security of supply. One is through storage projects such as dams and reservoirs; however, it is not expected that this provision will be adequate to completely mitigate the effects of climate change (Bolwidt, 2005). Indeed the World Bank and ICD envisage continuing activity in this direction, although it has to be questioned how long the trend can be supported given the high costs and environmental and social impacts. Dual usage for energy generation may, however, maintain its momentum, as hydropower is a sustainable energy source. As global temperatures increase, and especially in those countries where there is already a scarcity of resources, the efficiency of surface water storage will decrease and the marginal cost of development will continue to increase. As yet there has been no widespread use of artificial storage recharge (ASR) due to a variety of constraints; these are mainly related to concerns about pollution, although a large-scale groundwater recharge scheme using sewage effluent is under development in Perth, Australia. However, with new biotechnologies that can begin addressing concerns over pollution and water quality, ASR offers a means of at least partially controlling pollution and so

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better minimising losses. Resource development might well continue to be a preferred solution in many instances, especially in the developing countries. In high-income countries, maintaining and even increasing the amenity value of water and the environment that it supports is becoming increasingly important. This will not only mean greater competition between different, competing uses but also could change the essential character of "artificial" water bodies. For example, there are many examples of storage reservoirs in the planning phase meeting with vociferous resistance from environmentalists and subsequently being designated as Sites of Special Scientific Interest. This shift from "water mines" to ecological and recreational resources then leads to restrictions on use and constraints on their management for the original purposes. Other options such as desalination could become cost-effective for some countries that have the economic and energy resources to support them, but as a solution they would currently be deployed only in limited circumstances unless new technologies emerge.

The alternative response is to use existing resources more effectively through the application of demand management and recycling/recovery of water, to increase the intensity of its use. This is already happening, with industry in OECD countries such as Australia, Japan, the United States and Europe leading the way. However, this has been on the back of existing technology and systems configuration. For this approach to make any impact there has to be a step change in the intensity with which water can be reused. For that to happen, not only will new technologies that address problems of pollution and pollutant removal have to become widely available but physical infrastructure will also have to be adapted.

While demand-side management offers the possibility of making a unit of water work harder, in a global context water for urban and rural domestic consumption as well as that for industry will constitute only some 40% of total demand. Agriculture represents the biggest potential area for improving resource availability, in terms of both quantity and quality. The greatest impact could be felt in the area of biotechnology – with the possibility of engineering more water-efficient cultures – and ICT, which would bring about more effective water use in agriculture. Improvement could also come from a greater acknowledgement of the need to better manage the role of "virtual water" (water used to produce products), with changing crop production (in developing countries) and import patterns (in developed countries) (*New Scientist,* 2006). (Global estimated use of virtual water is some 1 000 km^3 per year.) It is also expected that new "water trading" initiatives will emerge, in which cities will be able to acquire agricultural allocations much more cheaply than new sources, expensive desalination or other systems (*e.g.* WSAA, 2005).

Environmental pollution brought about by economic activity will continue to be a problem, more especially in the developing and rapidly industrialising/

urbanising economies. It is unlikely, given the nature of legislation, regulation and its application, that levels of pollution will be significantly reduced anywhere other than in countries with well developed and applied pollution control measures, despite the attempts by WTO to act as an arbiter on internal behaviours. This stresses the likely importance of developments in technology that would allow for the detection and remediation of pollution before it gets into water service systems. There will be a continuing challenge of more complex, persistent and toxic materials that accompany technological development. The other concern will be pollution arising from extreme climatic events (droughts as well as floods) or as a result of systems failure (accident or sabotage). These problems require back-up and robust responses – perhaps necessitating redundancy in water service systems, as these may be minimised but cannot be entirely eliminated.

Overall, the environment is likely to be the greatest driver for adding costs to the future delivery of water services and managing the infrastructural impacts. The main factors are climate change and responses to this that may require large new infrastructure; expectations about security of quality and contaminant control to protect ecosystems; increasing uncertainties and the need to develop systems with in-built redundancy; and interactions across sectors such as water and energy.

Political changes

With the increasing trend towards decentralisation and more effective private sector involvement in water service provision, there will be political challenges. Many of these will be related to what the relationship between the centre and the local state is to be and how responsibilities are to be allocated. They involve accountability and governance in both the public and civil spheres. Regulatory frameworks, sets of obligations, and (especially) how the services are financed and revenue collected are all political matters. Change, however, has a tendency to be incremental and adaptive by nature in the face of institutional inertia and powerful élites rather than radical, except in the face of crisis (Hay, 1999). Given the potential technological changes outlined above, the probable increasing role of private sector participation in all aspects of water management will require a profound re-examination of the regulation institutions in all countries.

Continuing urbanisation will put a strain on local political institutions as they struggle to come to terms with increasing demands; finding the necessary financial and human resources to meet those demands; and the allocation of those resources – all this at a time when raising tax revenues is increasingly difficult. The nature of urbanisation will require a greater openness about the appropriateness, setting and achievability of levels of service and their sustainability. Institutions in the developing countries will

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have to adapt to cater for large numbers of poor people; part of the solution will lie in partnerships with civil society to deliver services. Transparency will be an important element that must go together with forms of public involvement and participation. Given these developments there could be a tendency towards centralising local control – forms of paternalism, when in fact the situations require the opposite course of action. The possible future configuration of water services provision will involve debates about the role of the state in the ongoing development of paradigms for the way in which water is seen and used (*e.g.* Hassan, 2001).

Overall, political changes are expected to increase the relative costs of future water service delivery, principally due to: planning, land use and urbanisation control processes; effectiveness of governance up and down the process; the forms and needs of revenue collection (which may not improve due to political will); increasing service levels to “be the same as everyone else”, driving infrastructure performance up.

7. Possible changes for the sustainability of current business models

In reflecting on the possible implications on business models, a distinction is drawn between a generalised situation in OECD countries, transition economies such as Russia and developing economies such as China and India. As already pointed out, there exists a wide variety of business models with varying degrees of private sector participation. This reflects the differing local historical and socioeconomic trajectories as well as the local physical context. The term business model should be understood in this context as referring not just to the actual business of service provision, but also to the institutional context within which it operates.

In OECD countries there is a relatively mature and stable business model in place, one that is increasingly looking for opportunities to market its knowledge and expertise within its economic sphere as well as outside. The principle of full-cost recovery is accepted and is increasingly an integral part of the regulatory framework. Affordability of the service is such that for most households, water services are invisible. The setting of tariffs is done in reference to other social objectives; thus water service providers could be given a greater degree of flexibility in their setting, in conjunction with regulators. That might also allow for other forms of revenue raising, so as to avoid basing everything on user fees. This could be of importance when it comes to raising income to meet wider societal requirements, such as mitigating the effects of climate change or risk provision – aspects that present a society with wide risk. Raising funds and investment in the light of growing needs will be a challenge. How this is undertaken will depend on the degree of autonomy that central government accords the decentralised service providers as well as the maturity of the financial markets. In this respect the OECD countries are well placed. The relatively stable political and economic conditions should facilitate the process of tapping into a range of financial instruments. The efficiency of revenue collection will make an increasing contribution to its performance. In general the one area that requires attention is that of regulatory oversight, which often does not provide the level of scrutiny required to ensure that the performance of water service providers can be benchmarked and provided with the necessary incentives to ensure business efficiency. This is particularly important as most services are delivered in a monopolistic way; competition is not the same as for most other types of service. Water service providers also need to strengthen their ability to engage with governments at a policy level in order to ensure that legal requirements – and, in the case of the European Union, directives – are practical and do not entail excessive costs. The ability to respond to and adopt new technologies and to implement them to best effect will be constrained by other factors, not just the capabilities within the service provider. Much will depend on planning policies and the ability of service providers to interact with and influence new urban and rural landscapes. Thus current business models are likely to become more sustainable and be well placed to cope with the identified trends.

In transition economies, affordability and the efficiency of revenue are matters of concern, together with the ratio of revenue to costs. These present problems for the continuing viability of business in those economies. The institutional and regulatory capacity will require strengthening, especially if there is to be a greater reliance on the involvement of the private sector. This appears essential in order to ensure that social and environmental objectives are met and there is adequate consumer protection with business-driven services. Investment and raising finance is likely to continue to present problems as, given the economic conditions, there will be structural constraints on the availability of funds and also the ability to tap into alternative sources of funding. The involvement of the international financing institutions will continue to be important. Much more support will be required in order to ensure the viability of the emerging business models.

In developing countries such as India and China, the key to success will depend on the forming and evolution of partnerships between local authorities, service providers (national and international) and civil society. While the problems between developing and transition economies are similar, the scope for India and China to overcome these is probably greater, given the size and pace of development of their economies. This economic growth should continue to stimulate interest in these countries, and their sheer size and diversity should be seen as positive assets. This reinforces the message that

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public-private partnerships will be both desirable and possibly even essential. It would be premature, however, to pass any definitive comment as to the viability and sustainability of their business models, as these are still emerging.

8. Summary and conclusions

Estimates of projected expenditure on water infrastructure have been made for the United Kingdom, the United States, India, Russia, China and Brazil, with other EECCA countries as outlined in Section 3. The baseline used for current expenditures has been estimated from the proportion of GDP allocated to water services, varying from 0.3% to 2%, although specific EECCA countries apparently have much higher rates, up to 6%. This gives a current global figure of USD 576.4 billion invested annually. In the future for the high-income countries, an investment rate of 0.75% of GDP has been assumed until 2015. For Russia, the OECD (2005b) figure of 0.32% of GDP seems an underestimate, but this has been used nonetheless to 2015. For China, 1.5% has been taken from the Five Year Plan (Section 3) and for India, the figure derived was 0.71%; for Brazil, Almeida and Mulder (2005) give an estimate of only 0.20%, which seems rather low but has been used. The projected GDP growth rates (World Bank, 2005) for EU countries to 2015 are assumed to average 2.3% p.a. overall, with US growth as 2.5% p.a., China 5.3% and India 4.1% p.a. For some countries there may appear to be seemingly high GDP growth rates adopted here. As noted earlier, in adopting broad figures the report has been informed by the available literature, which will tend to underplay individual circumstances. In the particular case of Mexico, for example, given the strong ties with the US economy, it is likely that the country will be influenced by US performance for the foreseeable future, potentially providing support for the projected growth.

Fay and Yepes (2005) proposed a general figure of 2% that has been adjusted slightly for middle-income countries, such as Poland and the Czech republic, to 1.9%, in line with the different sectoral allocation of investments between countries.

The potential effects of the main drivers that have been reviewed in Sections 3-7 have been considered in relation to each OECD country and others given in Table 5.16. The relative significance of each of the drivers in terms of how they are likely to influence the investment in water infrastructure in the ten-year period to 2015 has been qualitatively evaluated for each country and used to adjust the baseline estimates of proportion of GDP investment over the period. In 2005, the figures are assumed to be those initially defined as above, gradually changing to the adjusted figures by 2015. Beyond 2015, some of the lower- and middle-income countries will have moved to the high-income band and rates of investment have been adjusted accordingly (downwards as a proportion of GDP).

In estimating the changes in investment profiles as a result of the four main drivers, the effect of technology has been assessed as reducing the costs by some 6.66% on baseline. This has referred to an increase on typical current figures for efficiency gains for the England and Wales service providers at just less than 3%, but is estimated to be potentially some 6% by the economic regulator. For the other drivers, the costs have been assumed to increase by a total of some 33% as a consequence of environmental drivers (current UK estimates). The greater need to attract private sector participation and funding will mean that risk premiums will be higher, with more account of profit margins. Hence the increase for socioeconomic drivers has been taken to be some 25%; with the effects of internal politics it is slightly more than half of this figure at 15%.

It should be noted that the projected investments represent an estimate of what in an ideal world would be required to provide and maintain adequate levels of water infrastructure services for all sectors of a countries' economy and population. The projections illustrate the scale of the challenge that faces those at all levels responsible for planning for and providing water service needs, indicating that there is no room for complacency. Furthermore, it is unlikely that there will be any significant tail-off in investment requirements over time; rather, priorities will switch from infrastructure investment to infrastructure maintenance. Earlier it was suggested that the potential benefits in health terms alone have been estimated at USD 84 billion per annum, just for meeting the MDG – and this is simply for bare minimum provision of water services. Improving water infrastructure services would significantly reduce the costs of health care, lost productivity, loss of resources and other problems imposed on governments, the environment and on industry by water-related pollution. It has been estimated for China alone that the cost of pollution amounts to as much as 2% of GDP (Turner *et al.*, 2003). Globally the figure is not known, although it might be expected to be somewhat lower than this. In addition, water services are an essential part of any economy; without them, economic activity would be severely curtailed. Although the benefits are likely to outweigh the costs, it does not follow that these projected expenditures will be realised. Indeed, if past experience is any guide, it is certain that they will not be achieved.

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Table 5.16. **Projected expenditures on water and wastewater services**

	GDP ($ billion)	GDP/cap ($)	GDP growth (%)	Current exp. on water infrastructure ($bn)	Class	Projected expenditure on water infrastructure as % of GDP		Average annual investment ($ billion)		Main Drivers			
						By 2015	By 2025	By 2015	By 2025	Socio-economic	Technology	Environment	Political
Australia	602	29 893	2.3	4.515	HI	0.75	1.08	6.86	9.95	M	H	H	L
Austria	254	31 254	2.3	1.905	HI	0.75	0.89	2.59	3.91	L	H	H	L
Belgium	309	29 707	2.3	2.318	HI	0.75	0.69	2.75	4.38	L	M	M	L
Canada	1 050	32 921	2.3	7.875	HI	0.75	0.83	10.27	15.74	M	H	M	L
Czech Republic	187	18 370	2.3	3.553	UMI	1.9	0.85	3.12	2.83	M	H	H	M
Denmark	178	33 089	2.3	1.335	HI	0.75	0.89	1.82	2.74	L	H	H	L
Finland	152	29 305	2.3	1.140	HI	0.75	0.69	1.35	2.15	L	M	M	L
France	1 724	27 738	2.3	12.930	HI	0.75	0.83	16.86	25.84	M	H	M	L
Germany	2 391	28 988	2.3	17.932	HI	0.75	0.83	23.38	35.84	M	H	M	L
Greece	224	20 362	2.3	1.680	HI	0.75	0.81	2.17	3.34	H	M	L	L
Hungary	152	15 546	2.3	1.140	HI	0.75	1.37	2.02	2.79	H	H	H	M
Iceland	10	33 269	2.3	0.075	HI	0.75	0.69	0.09	0.14	L	M	M	L
Ireland	152	37 663	2.3	1.140	HI	0.75	0.69	1.35	2.15	L	M	M	L
Italy	1 620	27 984	2.3	12.150	HI	0.75	0.92	16.83	25.23	H	M	L	M
Japan	3 817	29 906	1.9	28.627	HI	0.75	1.26	46.98	63.41	H	H	H	L
Korea	10 30	21 419	2.3	7.725	HI	0.75	1.23	12.76	18	H	H	M	H
Luxembourg	28	63 609	2.3	0.210	HI	0.75	0.64	0.24	0.39	L	H	M	L
Mexico	1 006	9 887	2.4	190.114	UMI	1.9	0.85	167.78	153.65	H	M	L	M
Netherlands	477	29 332	2.3	3.577	HI	0.75	1.08	5.43	7.88	M	H	H	L
New Zealand	97	239 43	2.3	0.727	HI	0.75	1.13	1.14	1.63	M	M	H	L
Norway	184	40 005	2.3	1.380	HI	0.75	0.64	1.58	2.55	L	H	M	L
Poland	475	12 452	2.3	9.025	UMI	1.9	0.85	7.93	7.18	M	H	H	L
Portugal	194	18 503	2.3	1.455	HI	0.75	0.88	1.96	2.97	M	M	M	L
Slovak Republic	81	15 066	2.3	1.539	UMI	1.9	0.85	1.35	1.22	M	H	H	M

Table 5.16. **Projected expenditures on water and wastewater services** *(cont.)*

	GDP ($ billion)	GDP/cap ($)	GDP growth (%)	Current exp. on water infrastructure ($bn)	Class	Projected expenditure on water infrastructure as % of GDP		Average annual investment ($ billion)		Main Drivers			
						By 2015	By 2025	By 2015	By 2025	Socio-economic	Technology	Environment	Political
Spain	971	23 627	2.3	7.282	HI	0.75	1.06	10.97	15.96	H	M	M	L
Sweden	254	28 205	2.3	1.905	HI	0.75	0.69	2.26	3.6	L	M	M	L
Switzerland	230	31 690	2.3	1.725	HI	0.75	0.64	1.97	3.19	L	H	M	L
Turkey	530	7 503	3.5	10.070	UMI	1.9	0.85	9.33	9.66	M	M	L	M
United Kingdom	1 736	28 938	2.3	12.499	HI	0.72	0.86	19.14	27.96	L	H	H	L
United States	11 724	39 496	2.5	87.930	HI	0.75	0.64	101.65	167.63	L	H	M	L
Russia	1 449	10 179	3.5	4.637	UMI	0.32	0.85	11.49	26.41	H	M	L	H
India	3 291	3 080	4.1	23.366	LI	0.71	2.50	74.8	108.31	H	M	L	M
China	7 334	5 642	5.3	110.010	LMI	1.5	1.90	182.1	247.18	H	M	L	L
Brazil	1 462	8 049	2.4	2.924	LMI	0.2	1.90	19.8	32.02	H	M	L	H
Total				**576.42**				**772.12**	**1 037.83**				

Source: Authors.

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* *Endnote Profile: Past Trends in Selected Countries*

Mexico

Agriculture accounts for over 80% of water abstraction and 66% of total groundwater use. Groundwater also supports 70% of domestic and industrial water needs (Saleth and Dinar, 1999). By 1996 nearly 50% of the total public irrigation system had been transferred to water user associations. In the urban sector there have been reforms aimed at decentralising urban water supply away from central government to state and municipal governments and encouraging private investment. Central government retains responsibility for regulation, monitoring and enforcement, thus separating the management of resource issues from use and distribution. Urban access to drinking water was estimated at 96% in 2000, compared with 69% in rural areas (WHO, 2001); sewage and sanitation services had much lower coverage rates. Improvements in coverage between 1995 and 2000 were due to a national water programme, but this did not address the problems of low levels of maintenance and deterioration of assets. Water distribution is heavily subsidised by the government, which encourages overexploitation of resources and the under-financing of services. Only some 10% of wastewater is treated, despite effluents also being used for irrigating crops.

In 1989 the National Water Commission was set up at federal level to deal with water management by integrating water resource planning and management and co-ordinating efforts across the three levels of government (national, state, local). It acts as regulator at local level to finance and provide water infrastructure but not to operate it. This is the responsibility of municipalities and other local bodies; the private sector can also be involved (Hazin, 1997). In 1995 over 70% of water services were provided by municipalities. Levels of indebtedness are high among municipalities, with most public investment coming from the central government: 84% in 1994 (Hazin, 1997). This weakness is compounded by both a lack of technical and administrative capacity and lack of funds to cover operating expenses other than staff and administrative costs; the latter becomes more marked as the population size served by a municipality decreases. In an effort to address these problems there has been a programme to modernise water management companies, supported by funding from central government as well as from the World Bank, IDB and EBRD. As a result there has been an upsurge in agreements and concessions between municipal authorities and private water companies covering some 70% of the urban population (Barlow and Clarke, 2004).

The Mexico City metropolitan area holds over 20% of the country's population (22.5 million by 2010). The water supplied to users is heavily subsidised; the wealthiest benefit the most. Seventy-six per cent of the population live on low incomes. There are some 20 million houses, of which only about 51% have taps; 1.5% rely on public taps and 18.2% are supplied by private tankers, for which the charges are 500 times those of the domestic users. Bottled water demand is increasing by some 15% per year. The water system loses some 1.9 billion cubic metres every year due to leakage (UNESCO, 2004) and relies on groundwater for 80% of its supplies. Due to over-abstraction planners are now considering using sources up to 200 km away. To do this, the unit cost of water would have to rise from USD 1.34 to USD 5.36 per m^3, potentially making it unaffordable (Castelan, 2001). In addition, there are serious water quality concerns. Although there are 13 water treatment plants, many dating from the mid-1990s, they are frequently not in use due to either a lack of operating funds or a lack of water. In 1993 the water delivery system was subdivided among four water MNCs, which has led to charges of escalation of tariffs, high disconnection rates and underinvestment. In 1997-2000 the World Bank invested in a Master Plan for water for the city. Unfortunately, although there have been some improvements, there are cultural problems, with lack of commitment, limited institutional capacity and high costs of solving the major problems militating against substantial improvements. A major success has been the programme for water recovery (leakage management), which has recovered some 5 m^3/s at an investment cost of USD 50 million. This has offset the need for many of the major water transfers planned at a fraction of the cost (10%).

Australia

Australia, while seemingly very arid, has high localised rainfall (1 100 mm per year in the Sydney catchments) compared with other countries (the East of England has 450 mm per year). It has water infrastructure that in places is some 100 years old, but low leakage rates (10%). Due in part to high immigration and a series of droughts (the 1980s prompted action), efforts have been made to place water supply issues high on the government's agenda (*e.g.* CSIRO, 2005). Because of these pressures and responses and the existence of traditional Western technology, Australia may provide a good example of how provision and management of infrastructure in Europe – and possibly the United States and other OECD countries – may be delivered in the future, when climate and demographic changes start to force a reappraisal of the way current services are delivered.

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It is believed that there is already evidence of climate change in Australia, with droughts in the west and east and a longer-term reduction in rainfall in these areas of about 10%. Reduced rainfall is also responsible for a 50% reduction in observed river flow volumes.

Agriculture, which includes substantial areas of irrigated land, accounts for some 67% of total water use despite comprising only some 4% of GDP output (WSAA, 2005). Household use comprises some 9%, and 16% is used in various industries. There is major tension between the acute urban area needs for water, where abstraction costs are some AUD 1 000/megalitre, and farming needs, where charges are only AUD 40/megalitre. The other major challenges are to restore “environmental flows” to waterways that have been degraded due to over-abstraction and to meet increasing customer expectations regarding service levels.

Responsibility for water resources and management lies with each state and with local city and urban authorities, although central government has considerable influence controlling finances. In the 1980s a system of water licences was introduced, changing the way water was perceived and priced, and allowing water charges to be increased. Following rejection of the UK privatisation model in the early 21st century, reforms have introduced a hierarchy of organisations and delineated the respective spheres of influence for various government layers and water sector stakeholders; community involvement is very high and there is a mix of regulatory and economic instruments. In 2005, arrangements were introduced to allow third party access to the provision of water services. As yet there have not been any inset arrangements; it is thought that these would “cherry-pick” the profitable opportunities, placing a strain on the incumbent (public) suppliers. At the local level, corporatisation and privatisation of water undertakings in the urban and irrigation sectors have taken place, which has served to improve the sustainability of the systems.

All cities in Australia have water systems now facing problems of deterioration and the impact of urban development, especially on storm and wastewater management. This is in spite of the systems being well managed and maintained. Although Australian per capita consumption has been declining over the last two decades, due to the decline in industrial use and very effective water demand management, this trend has been and continues to be offset by demographic changes. For example, Melbourne’s population is expected to grow by more than 1 million in the next 20 years. The country is becoming increasingly urbanised with growth rates of 2% or more, and at the same time the number of households is increasing. As a result, the projected increases in water demand based on four scenarios for 2001-31 indicate that in some cases increases of up to 70% could occur (Birrell, Rapson and Smith, 2005). The expectation is that by 2020 most of the cities will be at full service capacity.

Currently there is a federal fund of some AUD 1.7 billion to finance a "National Water Initiative" and a number of major research programmes, such as the "Water for a Healthy Country" initiative (CSIRO, 2005). The reforms since the 1980s have produced savings in water use by demand management, recycling, reuse and the introduction of rising block tariffs. There have also been efficiencies in operational expenditure of some 20%. Other initiatives have seen water-efficient labelling and subsidisation (to the customer) of white goods and the introduction of "water trading". Across the country there is a diverse range of approaches, based on the idea that sustainability comes from resilience and diversity and avoiding "lock-in" to large-scale asset construction and use. There have been very detailed whole-life and sustainability studies (unparalleled globally) and the development of new technologies (*e.g.* NSW, 2004; Lundie *et al.*, 2005). Notably, there has been the move away from large end-of-pipe systems to more local and on-site management of water and wastewater. Desalination has been seen as a major option and a new plant is under construction to serve Perth. However, objections to the high energy use and concentrated wastes discharged have recently blocked similar plans for a desalination plant to serve Sydney (NSW, 2004; WSAA, 2005).

Brazil

Brazil is the fifth largest country in the world and as a country of almost continental size its climate and water resources vary. Water scarcity is acute in areas of population concentration and economic importance. With the majority of the population living in urban areas, the Brazilian economy is essentially non-agriculturally oriented; just 5% of the estimated usable cultivated area and 10% of irrigation potential are so far developed. In urban areas the coverage rate for access to water supply and sanitation services were 90% and 56% in 2000 respectively, while in rural areas they were 18% and 3% respectively. Those percentages are for a population of 170.1 million (USAID, 2002), although this national figure masks wide disparities between regions. Less than 20% of collected wastewater is treated. Coverage rates reflect the predominance of the large urban centres of Sao Paulo, Rio de Janeiro and others. Some 81% (138 million) of the population live in urban areas, many from rural areas. Water services have a number of different providers, including: state companies, of which there are 25 supplying some 95.1 million people with water supplies and sewage services to 39.8 million people; municipal providers and private providers to 40 municipal areas, mostly concentrated in the southeast region in midsize cities. Until the mid-1990s, 85% of the investment in water services was provided through the government, but since the 1990s this has begun to change. Both the federal government and states have privatised many of their assets including the enterprises responsible for water supply and sanitation services;

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this has shifted the burden of investment away from direct government involvement. In general, privatisation has proved easier at the municipal level where there are fewer legal constraints on actions such as granting concessions, which states cannot do (Media Analytics, 2002). Many of Brazil's publicly owned water companies have modernised and now operate on a corporatised basis, allowing them better access to credit and financing. A national water sector regulatory body set up in 2001 has started to take action to improve the long-term efficiency of irrigation. River basin committees are setting up water agencies to act as private or state-owned enterprises responsible for water resources development and management. These are in addition to the water services functions provided by or through state and municipal authorities. There remain, however, areas of concern such as co-ordination among all levels of government over water issues, addressing water pollution and water scarcity, and increasing cost recovery for services. In its 2005 economic survey, the OECD commented that "private investment in water and sanitation continues to be constrained by a lack of clarity over the assignment of regulatory powers across different levels of government. This has held back much-needed investment" (Dean, 2005). Overall, the water sector appears to be in a good position to strengthen its institutional foundations. However, recent construction projects to improve sewage treatment by building large new facilities in Porto Alegre, Greater Sao Paulo and other major conurbations have had problems due to financing and are proceeding in a "stop-start" manner.

Elsewhere in South America the situation is similar, with virtually no sewage treatment in El Salvador and Paraguay and highest levels in Nicaragua and Brazil. Where treatment exists, system performance may be poor, unmonitored or badly regulated. Waterborne diseases are thus endemic in a number of countries, such as Colombia. Citing a review in 1991, UNEP (2002) reports that the major issues in Latin America are: poor political support for wastewater treatment, linked to lack of environmental policies; financing, including a lack of indigenous institutional capacity and the form of financial models imposed by international agencies; and the need for more appropriate technologies.

Canada

Canada's water resources are considerable. It has an estimated 7% of the world's renewable water supply, the third highest percentage after Brazil and Russia. Almost 9% of its land area is covered by freshwater, including some 25% of the world's wetlands. However, for a country of just over 31 million people in 2003 and with a per capita GDP of CAD 29 700 (putting it in the top 15 in the world), it is not without water problems. Some 85% of the population lives within 300 km of the southern border with the United States while 60% of the country's freshwater drains northwards. The amount of water used in Canada has increased by nearly 26% since 1980, causing greater ecological stress and raising the costs of maintaining adequate water infrastructure (*http://environmentalindicators.com*). In 1999, about 26% of Canadian municipalities reported water availability problems within the previous five years (Environment Canada, 2005).

Just under 95% of Canadians have access to adequate water supplies and sewage services. Of that share, some 97% had primary and 78% secondary or tertiary wastewater treatment. However, while it is safe to say that infrastructure in western parts of the country is generally newer than infrastructure in the east, it is difficult to make further regional generalisations. For example, while Calgary has a water treatment system that is state of the art, the City of Victoria, also a western city, has no water treatment system at all. In fact it remains one of the only cities in Canada that dumps untreated sewage directly into the ocean. The discrepancy among different municipalities is partly a result of how sewage and water treatment is regulated in Canada: generally, it falls under the jurisdiction or authority of many different levels of government. National, provincial, municipal and in some cases even international laws and standards apply to sewage treatment (*www.environmentalindicators.com/htdocs/indicators/7muni.htm*).

The vastness and diversity of the country's geography also has a significant impact on infrastructure financing needs, and one of the most striking examples of this exists in Northern Canada. Communities in the North already face tremendous infrastructure challenges as a result of the relatively small tax base and physical remoteness of many communities, but also due to the logistical and technical difficulties of building on permafrost and withstanding extreme climate conditions. Water infrastructure in particular can be very different in the North than in the rest of Canada, with many communities relying on trucks rather than pipes to deliver freshwater and dispose of wastewater. Additionally, climate change, which is being experienced most acutely in Northern Canada, is having direct impacts on infrastructure in the North. Melting permafrost, erosion, and the unpredictability of the ice-road season are creating increased demands for investment in new and innovative infrastructure in order to adapt. At the same time, the unpredictability of climate change is making it difficult to identify when and where these investments need to take place.

Heightened concerns about flooding and drought as a result of climate change are also affecting investment needs in water system infrastructure. For example, Infrastructure Canada recently committed CAD 120 million to expanding the Winnipeg Red River Floodway, which has saved the city from flooding over 20 times since it opened in 1968, but which in recent floods has been filled almost beyond capacity. There is also growing interest in developing innovative regional water distribution systems for rural and agricultural communities.

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In 2001, Canadians used 335 l/c/d, and at least half of this amount is "unnecessary and wasteful" (Environment Canada, 2005). Canada's per capita consumption is 65% above the OECD average; only the United States has a higher per capita consumption. As the 1987 Federal Water Policy observed, water is the most undervalued and neglected of Canada's natural resources. Municipal water use accounts for some 12% of all water withdrawals, slightly less than manufacturing at 14%. Although manufacturing has reduced overall gross water use through recycling, consumption rates have gone up as the economy has grown. In addition, at least 40% of discharges are untreated.

Although much of the water infrastructure was built in the first half of the 20th century, the development of the country is reflected in the diversity of water infrastructure statistics. According to McGill University (1996), in 1995 the average age of municipal sewage treatment infrastructure in Canada was just under 25 years; the average age of municipal storm sewers was about 32; and municipal sanitary and combined sanitary and storm sewers was about 41. However, in Toronto for example, 17% of water mains are 80-100 years old and 7% are even older. High population growth has been focused on a limited number of large metropolitan centres. About two-thirds of the population live in these areas; the largest seven account for 45% of the total population. Water infrastructure was well maintained until the 1970s, due to good economic conditions and the fact that many of the facilities were built after 1945 and so relatively new (Infrastructure Canada, 2004). Most agree that since then there has not been the required investment in the maintenance of the infrastructure. As a result, deterioration of water infrastructure has become a significant problem. It has been estimated that to repair Ontario's water mains costs CAD 40 million a year, that water losses are around 40%, and that 25% of the water system must be replaced and 50% restored over the next 60 years (Infrastructure Canada, 2004). According to a 1996 survey of 167 Canadian municipalities, 59% indicated that water distribution infrastructure was in need of repair. The situation for wastewater infrastructure was worse: 68% of the sewer systems were reported to be in need of repair. For example, in Ontario in 2002, 61% of water treatment works failed inspections and in 2001, 101 sewage treatment works violated provincial laws or guidelines (Brubaker, 2003). At the same time, new standards, design requirements, regulatory demands and stricter environmental and health regulations have increased both the need for upgrading and capital and operational costs. Three decades of deferred maintenance work have created a situation where deterioration will escalate exponentially if no action is taken (Mirza and Haider, 2003).

Local government capital spending has been on a downward trend for the past two decades (Vander Ploeg, 2003). Charges for some water services do not cover the costs of municipal water and wastewater services, such that use is being subsidised with only half of the operation and maintenance costs being recovered in some communities. The tightly controlled fiscal framework limits the ways in which municipal authorities can raise funds and increase revenues. This has contributed to the increasing infrastructure deficit and has led to a growing preoccupation with how to finance infrastructure (FCM, 2001; Infrastructure Canada, 2004a; Vander Ploeg, 2004). However, in western cities the water and wastewater infrastructure is often in a better position, ascribed to the relative youth of those cities. Also, such services are more frequently paid from user fees, making the financing of infrastructure improvements easier than it would be if it depended on the municipal tax base (FCM, 2001).

Under Canada's Constitution Act (1867), responsibility for water is divided between the federal and provincial governments. Provinces are the "owners" of water resources, while the federal government has specific responsibilities with respect to such matters as fisheries and navigation. The 1970 Canada Water Act entrusted the federal government with providing national leadership in freshwater management. Since 1987 the Federal Water Policy has provided a framework for water-related activities of all federal departments. Contributing to the complexity of water governance is the fact that local agencies such as municipalities and water management agencies also play an important role, but are creatures of provincial governments. Overall, provincial governments are responsible for long-term as well as day-to-day management of water resources. This includes policies, regulations and strategies covering drinking water supplies, the protection and conservation of water quality and quantity, and aquatic ecosystems. In order to promote better management many are moving to integrated ecosystem and watershed management approaches, and several have created institutions that focus on specific water issues such as apportionment. At another level there are also collaborative bodies that link specific federal, provincial and territorial spheres of interest – for example, the Canadian Council of Ministers of the Environment, which developed water quality guidelines.

China

Only 47% of the Asian population have improved sanitation coverage, by far the lowest of any region of the world. Asia has 80% of the global population without access to improved sanitation, and almost two-thirds do not have access to improved water supply. With just 31% coverage, the situation is much worse in rural areas than in urban areas, where coverage is 74%. Water supply coverage is 81%, the second lowest after Africa. Like sanitation, coverage is lower in rural areas (73%) than in urban areas (93%). Currently, approximately two-thirds of the Asian population live in rural areas, but by 2015 the urban population is projected to represent 45% of the region's total, and should reach just over one-half by 2025. This population growth and shift will place enormous strains on already overburdened urban services. If adequate provision for sanitation in large cities is taken to mean a toilet connected to a sewer, there is a lack of adequate provision in cities throughout Asia.

Not only is China the world's most populous country, but its geographical sweep is huge. There are thus major differences between regions, and any generalisation can be very misleading. Renewable water resources have been estimated as being 2 711 billion m^3 from surface and 829 billion m^3 from groundwater; respective withdrawals have been estimated at 425 billion m^3 and 86 billion m^3. Water availability is unevenly spread over the country and China is prone to both floods and droughts. The north and northeast have over 40% of the population and 60% of the cultivated land but only 15% of the water resources. Added to this are concerns about groundwater mining from the North China Plain aquifer, an important grain-producing area and source of water for several major cities; were it to fail the consequences could be catastrophic (World Bank, 2001). Agriculture accounts for some 73% of water use, with 10% domestic and 17% industrial. The growth in irrigation needs is 0.5% as compared to 5% for non-irrigation needs. Of the total water consumed, 80% comes from surface water sources and the remainder from groundwater and reuse. Of particular concern are the shortage of water supply in some 600 cities, mostly located in the economically important northern part of the country, and water pollution. Already some 400 cities face water shortages, mostly due to environmental pollution (RFA, 2005), and some 600 million people risk drinking contaminated water. The total shortfall has been estimated at 6 billion m^3 (Jingrong, 2004). Beijing, for example, has experienced difficulties since the 1970s, with predicted shortages of up to 1.64 billion m^3 (annual rainfall 10 billion m^3) by 2010. The city has recently been considering new sources up to 1 000 km away, together with further development and control of local surface and groundwaters, and a lot of new small and local interception dams. This will also help with water reuse for irrigation. In addition, some 2.45 million m^3 of drainage from urban areas is seen as a potential for reuse following treatment. Locally, water saving measures and storm water storage is being introduced into the city (Nie and Schilling, 2000).

In 2002, per capita consumption in urban and rural areas was 219 l/h/d and 94 l/h/d, respectively (USITA, 2005). China expects the net increase in water demand to reach 40 billion m^3 by 2005; over half will be needed in cities and towns, where at present there is 77% network coverage. Supply systems built in the 1950s are experiencing serious deterioration. Agricultural demand is expected to stagnate or decline as a result of improving efficiency and technology. Wastewater treatment is set to rise from an estimated 20% to 45% by 2005 and to 60% in the larger cities (USITA, 2005). In 2002 only 310 out of 660 cities had municipal wastewater treatment works, with none in most of the 17 000 towns. There are over 61 000 industrial wastewater works, owned by the enterprises that treat 85% of discharges (USITA, 2005). Only in areas of severe water shortage is there any concerted attempt to reuse wastewater. A 1993 ESCAP study found industrial water use to be highest in the Yangtze River Basin (including Wuhan), where 25% of all water extraction was for industry. The highest urban water use was in the Hai He-Luan He basin (which includes Beijing). Almost 9% of the total water use was for urban supply. While most of the water is used for agriculture, the increase in agricultural water consumption has been low. The Nanjing Institute of Hydrology and Water Resources estimated that from 391 billion m^3 in 1980, agricultural use by 1993 was 406 billion m^3 (50% of all water used) and 394 billion m^3 in 2002. Use for irrigation declined by over 4%, from 358 to 337 billion m^3. However, an increasing amount of this water was from the ground. Of the 1.3 billion population, some 80% were living in rural areas in 1999. The use of human wastes for fertiliser for agriculture is widespread and has been practiced for more than a millennium. However, poor practices meant that in 2001 some 50% of the rural population were infected by ascariasis and 63% with helminth. Although more than 85% of the total population has access to some form of latrine, less than 15% of these facilities were considered safe in a UNICEF survey in 1999 (Hua, 2000). New initiatives are needed to promote the uptake of properly planned ecosanitation systems.

Industrial water use in southern China has shown the biggest increase (in percentage terms) from 1980 to 2002; urban water demand grew by 470%, from 6.8 to 32 billion m^3.

In 2002, China began a massive south/north diversion of water, with three canals planned to link the country's four main rivers, including the Three Gorges project. Much of this is scheduled to be in time for the 2008 Olympics. The total cost is estimated to be USD 22 billion, with the construction of the west route cost at USD 36 billion. A limited liability company will oversee the main work and there are plans to establish provincially based companies for the associated auxiliary infrastructure. Such water diversions are causing reductions in river flows, a 26% loss of wetlands and the drying up of 2 000 lakes, affecting the Yellow River (Ramirez, 2005).

Between 1950 and 2000 the urban population increased by over 500% and now accounts for some 40% of the total (UN, 2002), with 72% of growth by rural migration. By 2030 about 60% of the population – some 883 million people – will be urbanised (Hugo, 2003; OECD, 2005). Such growth is placing enormous burdens on urban water supply and sanitation systems. The economic growth rate over the last 20 years has averaged 9.5% and is expected to continue at high rates (OECD, 2005). In 2003 China was the largest recipient of FDI, at USD 53 billion. The private sector is now a major force in the economy and is one of the main engines of jobs and growth; with further urbanisation it could add to the reduction of inequalities. A major challenge is to reduce the pollution accompanying urbanisation. Although there are an increasing number of wastewater treatment works, only a third are functioning well. This is due to a combination of low funding and fee collection and insufficient government monitoring and law enforcement (Turner *et al.,* 2003; McGill, 1999). Pollution monitoring and law enforcement are poor due to weak institutional capacity at all levels. There are also problems in raising the required finances, mainly through the use of enterprise bonds and other mechanisms such as public-private financing partnerships (Turner *et al.,* 2003; McGill, 1999). Although government policies have contained levels of pollution generally, water pollution remains high and the extensive use of resources such as water is beginning to pose problems for economic development (OECD, 2005). One-third of the major water basins are classed as highly polluted and 75% of the water flowing in urban areas is unsuitable for drinking. At the same time there is considerable scope for improving efficiency in the use of irrigation water (OECD, 2005).

China it is still a politically centralised system, although there is now a considerable degree of decentralisation of power at national, provincial, prefectural, county and community levels. Legislative and regulatory powers as well as planning and development are the responsibility of national government but the management and maintenance of water systems are the responsibility of the various lower tiers. Municipal governments are primarily responsible for providing water and wastewater services; they own and manage more than 60% of water capacity. Responsibility for the water sector is split between the Ministry of Water Resources and the Ministry of Environmental Protection. Although the administration is vertically integrated there remains a substantial degree of functional specialisation and management decentralisation across government layers. This decentralisation causes conflict across government and is further complicated by the presence of state-owned water enterprises, which have their own agendas. There have been a number of legal instruments passed to strengthen powers in this area, including clearer lines of responsibility and financing; bridged gaps between environmental protection, water supply and pollution; demand management; and property rights. An increasing number of policy initiatives aim at adopting economic instruments, in some cases making government funding contingent on introducing full-cost pricing. But given that prices for services in general are held below full cost, this imposes financing constraints on the provision of services (OECD, 2005). Tighter budgetary constraints may, however, lead to some hard choices.

In 1997 private and non-governmental organisations were allowed entry to the water sector, and all public water projects were supposed to be run along commercial lines. There are requirements for local governments to draw up integrated water management plans; municipal undertakings have been reformed and government has separated service delivery from regulation. Emphasis has been on economic growth and devolution of authority. This has resulted in institutionally weak environmental protection and corruption at all levels. Reforms have strengthened the financial position of the state, contributed to a rising standard of living and the growth of per capita water use, and increased water pollution and competition for the dwindling water available (Elizabeth Economy, 2005). If these trends continue there could be up to 30 million "environmental refugees" forced to migrate because of lack of water for arable land, searching for work in the cities.

Between 1981 and 1993 the annual investment in urban public water facilities increased from USD 45.6 million to USD 743 million. There are efforts to encourage development outside of the existing economic growth areas through the central government's "Go West" programme. The areas targeted lack the necessary water infrastructure and require investment in improving supply, sanitation and wastewater treatment as well as institutional strengthening. One such endeavour is being supported by the World Bank with a loan of USD 180 million out of the total estimated cost of USD 280 million. This is being complemented by the Asia Development Bank's initiatives in the poorer inland provinces in the water and wastewater sectors.

India

India is the second most populous country in the world and in terms of land area the seventh largest. Agriculture accounts for 84% of water use, with domestic supply accounting for only 5% and industry the remainder. It is expected that non-irrigation demand will quadruple due to population growth, urbanisation and economic development, although India is likely to remain essentially an agricultural nation for some time to come. Between 1950 and 2000 the urban population increased by over 350% and now accounts for some 30% of the total (UN, 2002), or approximately 280 million people. By 2030 some 40% of the population will be urbanised, accounting for some 575 million people (Hugo, 2003), living in over 4 378 towns and cities and contributing in excess of 60% 0f the country's GDP. The population is expected to stabilise at an estimated 1.5 billion by 2050. Of the urban population, 90% had access to clean drinking water in 2002 (Planning Commission, 2002) compared to 85% in 1993, although the corresponding figures for the rural population are 78% in 1993 (WRI, 1995) and 70% in 2002. Some 19% of rural households have a toilet compared to 80% in urban areas (Planning Commission, 2002). Sewage systems are present in only 70 out of the 300 major cities, and only 30% of wastewater generated in municipal areas is treated (Planning Commission, 2002), and not necessarily to a good standard.

Between 1950 and 2000 the gross irrigation potential increased from 19.5 to 95 million hectares, and further increases are expected. India has a wide range of geography and climate that influences water resources, utilisation

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and agriculture. In general, agriculture relies on the seasonal monsoon rainfalls: 50% of precipitation falls in just 15 days and over 90% of rivers flow in just four months, a variability that brings both drought and flood. Most of the interior is arid though fertile, meaning that agriculture could be expanded. In India's 2002 national water policy, drinking water was given the top priority in water allocation ahead of irrigation, which has significant implications for future water sector development. Nonetheless, some 21 million farmers now use underground water for irrigation of two-thirds of India's crops, and this takes out some 250 km^3 of water per year that is only being renewed at a rate of 100 km^3 per year (New Scientist, 2006). Currently it is estimated that around one million new groundwater pumps are installed annually to increase crop irrigation. Not only are there no data on the distribution of the pumps, but they are entirely uncontrolled as well as being subsidised by government.

There are associated problems between states over the management of transboundary water resources; these are expected to worsen in the future, with a growing disparity between supply and demand for water (Shadananan Nair, 2004). There are further problems connected with the overexploitation of groundwater, brought about by the increasing use of small motorised pumps. In 2000, India's 81 million land-owning families had some 20 million tube wells and pump sets, a figure that grows by 500 000 per year. Unregulated use and cheap electricity has depleted aquifers, which has meant ever deeper wells and increased costs. This also poses severe problems for rural water supply, as these wells are the major source of drinking water. In addition there is concern over leachates from agriculture causing increasing aquifer pollution. The pollution and deterioration of groundwater in many areas is a matter of increasing pubic health concern, as is the quality of many of the rivers used by municipal authorities for drinking water supply, which are heavily polluted (TERI, 2002).

Although there is a strong central government, the lack of constitutional powers makes it weak with respect to the co-ordination of the water sector. That leaves the sector and its institutions relatively constrained in what they can achieve in terms of planning and water management (Brisco, 2005). National water supply and sanitation strategies are set out in successive five-year plans. The nodal agencies for rural and urban water supply and sanitation are the Rajiv Gandhi National Drinking Water Mission and the Ministry of Urban Development and Poverty Alleviation. Urban infrastructure facilities are provided by local urban bodies that depend on central and state governments for grants and loans. Other problems are the negligible user charges, corruption, high staffing levels and an enormous backlog of deferred maintenance (Brisco, 2005). Budgetary allocations to the water sector are falling, as are payments by users. The situation has to an extent been alleviated by the "era of individual coping strategies". For rural populations it is the tube well that taps local aquifers; for the middle classes and industry there are other self-provision strategies. For the urban poor there is only the water vendor. Progress in introducing sectoral reforms after 1999 remains slow, though there has been some localised progress (Saleth and Dinar, 1999). Central Government has identified the need to reform the way infrastructure development is governed if it is to meet the target of 100% coverage of the urban population with water supply facilities and 75% with sewage and sanitation by 2007. The funds required for this purpose are estimated at INR 53 000 crore, the majority of which would come from the states (*http://indiabudget.nic.in*). How this translates down to states and to local bodies remains to be seen.

Following reviews by the World Bank and the government of India, interest in privatisation has been increasing and some states have created autonomous corporations to mobilise private funding. Over the past ten years the World Bank has been working with the Ministry of Urban Development to promote private sector participation. Success has been somewhat mixed, with many proposals failing and 25 large and small contracts being abandoned after starting. A recent report noted some successes, however (UNRISD, 2005). For example, in 1999 the urban centres of Madras, Poona, Bangalore and Hyderabad were successful in attracting private participation in the form of management contracts and concessions in the water sector. This trend has been continuing, with many other examples of the private sector gaining concessions to supply municipalities, industry and even rural areas in spite of sustained vocal opposition (India Resource Centre, 2003). There are concerns that the controversies surrounding the involvement of the private sector are hindering the search for solutions to the chronic water shortages experienced in most cities and urban areas. In Delhi for example, only 2.9 million m^3 of water are supplied intermittently, as against a demand of 4.2 million m^3 per day, to the 60% of the people who have water connections. For the rest they rely on illegal connections, tankers, standpipes or handpumps. Delhi's water board is planning to let pilot management concessions costing an estimated USD 246 million, retaining the right to set tariffs. However, in 2004 revenues covered only 60% of operating costs. To raise tarrifs would require accurate and reliable water meters – which have not so far been installed (*The Economist,* 2005). India has demonstrated that it can improve its water sector but this requires removing the obstacles to water being priced properly and developing a private financial infrastructure that can fund developments (Mulford, 2005). The government has acknowledged that financing will have to be based on user charges, and has introduced a range of incentives to encourage the private sector to participate and municipal corporations to make use of bond issues, although so far on a limited scale (*http://indiabudget.nic.in*).

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Europe

In Europe the overall abstraction and consumption of water resources is believed to be sustainable, although there are marked regional variations and the effects of climate change may challenge distribution. During the 1990s there were decreases in water abstracted for almost all uses in most parts of Europe, the decrease being most marked (30%) in the Central EU accession countries. However, in Southern Europe seasonal water shortages are becoming more acute as agricultural and tourist demand for water increases. The southern European countries have the most land under irrigation and are also among the most inefficient in their agricultural usage (Vecino and Martin, 2004). On average, 33% of total water abstraction is used for agriculture, rising to 50% and more in southern European countries. It is also these countries that have the greatest area of irrigated land, with an average usage of 7 000 m^3/ha, which compares to figures of between 500 and 2 000 m^3/ha in other parts of Europe. By contrast, urban use accounts for some 16% of all water abstracted and industry 11%, with energy production (cooling) being the most extensive user of abstracted water. Per capita urban water use has shown a small decrease since 1990 although the actual amounts vary across Europe according to factors such as climate, the levels and efficiency of public water supply, water use habits and how water is paid for. Some of the falls in usage have been the result of an increased focus on water savings measures and the introduction of water charges and tariffs (*e.g.* Butler and Memon, 2006). However, loss of water from water systems remains a serious problem.

Absolute water use has increased as a result of more people being connected to water supply systems through demographic changes, such as more households and increased wealth and standards of living. In Europe the percentage of the population connected to a public water system is generally over 90%, although there are regional differences. In Eastern Europe the proportion of urban households connected to piped water supply is generally over 80%, with coverage in the rural areas ranging from 10% in Romania to 90% in Slovenia and Bulgaria. In the former eastern bloc, urban water use has decreased as a result of industrial decline, tariff increases and improvements to the supply systems. In contrast, Bulgaria and Romania have high water use per capita as a result of poor supply systems and all the problems that attend these. Per capita household water use varies from a high of between 224 and 265 l/capita/day in Spain and Norway to lows of between 85 and 115 l/capita/day in Lithuania, Estonia and Belgium.

Across Europe, there are major differences in subsidiarity traditions, and thus the role of local governments. According to Juuti and Katko (2005), this difference is crucial for the evolution of and strategic decisions concerning the management options for water and sewage services. Most significant is the role of the private sector in delivering these services. Clearly this is now strongly related to the globalisation and diversification of a relatively small number of large corporations that are major actors in water service provision.

The development of water services in 29 cities across Europe has been examined in detail by Juuti and Katko (2005), reporting on the EU WaterTime project. The historical factors creating demand for water services are varied; the most important were: the state of the service providing business; fire protection; lack of readily accessible water; poor water quality; environmental protection; public health; industrial needs; regional perspectives; and tourism. These demands can be exerted at different times in the development of each city. The strong role of fire fighting and associated insurance services is cited as a primary driver for a number of cities.

In each country studied, it was found that although private finance initially provided water services (in a less than comprehensive way), subsequent responsibilities were taken over by municipal provision by the beginning of the 20th century. Interest in environmental protection for receiving waters did not develop until the 1960s-70s although most countries had some form of wastewater treatment by then. After the Second World War most of the Eastern European systems were managed under centralised state control, rather than at a municipal (city) level. In the latter part of the 20th century, most European cities introduced separation between the storm and sanitary drainage systems, although due to historical instillation, most sewers in Western Europe are still of the combined type; only new systems are separate. Few countries – the Netherlands and many cities in the United States are notable exceptions – are attempting to retrofit systems for the separation of storm and sanitary wastewater. In London for example, there are plans for a new combined storage sewer at a cost of USD 3 billion, which uses essentially the same technology as for the originally constructed interceptor sewers in the 19th century (Thames Water, 2005).

Renewed interest in private operation and ownership of water services emerged in Europe in the 1980s-90s. Despite this, the only fully privatised services for water and sewage in Europe are in England and Wales; in the other constituent countries of the United Kingdom, these services are provided differently. Various other forms of private involvement exist, ranging from simple contracting services to partnering and municipal or state-owned dedicated companies. Even state operation can be varied, with federal operation in some countries, municipalities in others and segregation between the various water service components (water, sewage, storm water) in others. Mohajeri *et al.* (2003) provide a comparative review of private sector involvement within the water sector across the (then 14) member states. Diversity is and will remain a main principle of the EU, and these various forms of service provision are likely to continue but with dynamic shifts and

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partnering across and within service groups. There is strong evidence of multi-utility presence in many EU countries, with perhaps fewer and fewer major players in the water market over time. Reconciling the delivery of the Water Framework Directive with the need to better engage stakeholders and also to ensure that they pay the full economic cost for water services – and within a very short timescale (2015-17) – will be challenging for Europe and inevitably allow more of the experienced and larger private companies to engage in the market and operational opportunities. The needs to upgrade water infrastructure are the greatest in the newest European countries, but it is also in these countries that the economic challenges are likely to be greatest (Fankhauser and Tepic, 2005).

The Watertime project provides an illustration of the changing water consumption patterns for some of the European cities investigated, as shown in Annex Figure 5.A1.1. These results are believed to be an underestimate of the actual water usage. Several reasons are given for the general decline in consumption since the 1990s: the energy crisis in the 1970s and charging for sewage treatment linked to it; the decline in industries using centrally supplied water; general water efficiency awareness and drive; and metering.

Forms of revenue raising are also crucial for meeting demands for water-related services. In some countries water services are provided using revenues from general or local taxation, whereas in others it is the "customer" who is directly charged for the water used. Where properties are metered there should be a greater awareness of the need to conserve water (although not for the wealthiest), yet evidence suggests that typically less than 10% of demand can be cut by retrofitting water meters (Butler and Memon, 2006). Declining water use has a knock-on effect for tariffs, with lower income for suppliers. Hence a number of structural changes were instituted in a number of the Baltic countries in order to ensure supplier viability.

Additional data suggest that there has also been a decline (less marked than in Annex Figure 5.A1.1) in billed domestic water consumption in nine of the cities studied in the Watertime project. Notwithstanding these results, a separate review of domestic water use across Europe (Wieland, 2003), had slightly different results to what may be interpreted from Annex Figure 5.A1.1 in terms of whether or not demand was declining, as given in Annex Table 5.A1.1.

The table possibly underestimates domestic usage, as in some countries consumption is determined based on the total domestic supply divided by the total population, and a significant number of households may not in fact be connected to "public" supplies. For example, in 2002 only some 54% and 72% of Romanians and Estonians respectively were connected, although supposedly almost 99% of Bulgarians are and have been connected since the early 1990s (Eurostat). Table 5.A1.1 shows that in a 15-year period demand has fallen in the new countries (where there are more private supplies) and risen in Nordic countries. The highest demand was found to be 214 l/h/d in Finland. In Germany, Belgium, the Netherlands, Austria and Denmark, water charges were relatively high and hence water use is lower.

Most water in Europe is abstracted from surface water sources (70-90%). An exception is Denmark, which is entirely served by groundwater. Public water supplies represent less than 20% of total overall demand and predominantly originate from groundwater, although trends now show that there is an increasing reliance on surface supplies. The highest overall abstractions in the EU region for all uses are in Greece, Portugal, Spain and Italy; the highest demand for public supplies is in Belgium, Iceland and Norway. Data on distribution system leakage rates are sparse. In England and Wales leakage currently stands at 150 l/h/day (2004-5), representing some 20% of piped supply and the average per capita daily consumption of one person. Households and small business users of public water supplies are classed as "domestic". In Finland, these users consume all of the supply in this sector, whereas in Bulgaria only some 34% of the public supply goes to domestic uses. Annex Table 5.A1.2 shows that across Europe, domestic usage can be viewed through three groups, and compared with uses in the EFTA countries. There is no correlation between domestic use and the proportion of the population connected to public supplies.

Water supply quality is heavily regulated across Europe, with the Drinking Water Directive covering the primary standards.

Europe has a wide variety of institutional arrangements for water resource management and water supply, ranging from direct public management to delegated public management, delegated private management and direct private management (EuroMarket, 2005). In the Netherlands, 20 corporatised water utilities run the water supply system while wastewater remains a municipal function. In France there are some 16 300 water suppliers, mostly controlled by three large private concerns operating under franchise agreements with local authorities who own the assets. They supply some 75% of the population and 52% of all sewage services (Renzetti and Dupont, 2003); the rest are served by municipalities.

Spain also operates a system of delegated management but to a lesser extent than France, with 37% in private hands and with the state having an interventionist role, particularly with regard to agricultural water supply. In some parts of Germany, public-private consortia act as service providers while in other parts supply is managed by municipalities. For example in Bavaria, one of Germany's 16 Länder, there are over 3 000 municipal water works. In the United Kingdom, arrangements include private water companies, corporatised public provision and provision by a government department. In

Italy there have begun to be changes to the public provision of water services, partly brought about by the Water Framework Directive. Private water concessions to consortia (often headed by the big international water undertakings) by municipal authorities are being implemented under a 1994 law. In addition, corporatised municipal enterprises are beginning to operate beyond their own home territories. The trend in private sector participation has gradually increased over the past decade in southern member states (EuroMarket, 2005). The predominant model of water supply and sanitation, not only in Europe, is in one form or another of state-owned utilities fulfilling that function. Less than 10% of all people globally get their water from privatised or part-privatised businesses (SAM, 2004). Overall in Europe 48% of the population is served by water supply systems under public management, 15% by public water companies (Germany and the Netherlands), 20% by delegated private management (mostly France and Germany) and only 1% by direct private management (England and Wales) (Bakker, 2005).

Throughout Europe water tariffs have been increasing at between 2% and 6% per annum (OECD, 2001) although the levels of water prices are lower than the cost recovery levels. There are few examples where tariff structures have been designed to aid demand management (Roth, 2001) and often those few include substantial subsidies. Although over the last 10 to 15 years there have been moves to better cost recovery, it is only in the case of domestic use that any real improvement has been made, partly supported by greater metering coverage. There are, however, marked differences in approach across the EU. While more countries have introduced volume-based charges, in southern countries social concerns and equity are important and so systems such as block tariffs are more prevalent. In the industrial sector 75% of water used is not drawn from the public system and even where it is little information is available on price levels (Roth, 2001) but it would appear that cost recovery is below that for domestic supply. With respect to agriculture there is a marked divergence in tariffs between Northern and Southern Europe. In the south, equity considerations predominate; in the north, water use is almost always charged by volume used.

A common feature that emerges is that the water infrastructure systems built since the 19th century have been provided by the state (national, regional or local) as these could not have been financed privately. As a result of this public investment, the degree of access to water services and the level of coverage achieved has been very high. Over the past 20 years the main driver behind water services has not been the need to extend the services provided. Rather, at present the need for capital-intensive investment in water infrastructure arises from the need to meet new standards and requirements or from new developments. Apart from this, all water service providers in Europe are facing similar problems. Modernisation of the existing systems is overdue;

they are ageing and deteriorating, and in doing so are creating problems with respect to both water quantity and quality of supply. Apart from the key issue of maintenance associated with deterioration of assets, the other overarching factor influencing the water sector activities are EU directives and particularly the Water Framework and associated directives. Meeting directive obligations has in the past been a key driver of effort and expenditure, including research and development. Many of the directives are associated with environmental quality and (to a lesser extent) social concerns. These and especially the WFD will continue to require substantial investments and expenditures on the part of all EU member states. For example, a recent estimate of the cost to the United Kingdom of the Priority Hazardous Substances Directive is some USD 10 billion (Ross, Thornton and Weir, 2004).

A review of water and wastewater programmes in Central and Eastern Europe (Secrest, 2001), identified a number of common issues to be addressed. Infrastructure was severely degraded due to age, a situation exacerbated by lack of maintenance, lack of performance incentives, high costs, low cost recovery and low levels of service. Tariffs generally did not reflect the full cost of the service, and the presence of cross-subsidies tends to favour domestic consumers. In many cases revenues only cover 60% of operational costs, leading to a downward spiral of poorer service. In addition, the low level of service and low tariffs reduced the incentives for customers to conserve water, and high non-payment rates (20-30%) were common, often due to the small number of industrial customers who comprise a large part of the revenue stream. As a result the projects studied aimed to improve the operating performance of the water systems and at the same time develop the institutional base of the utilities through a range of sectoral legislative, regulatory and institutional reforms. The slow progress in reform at municipal level is seen as the biggest obstacle to the improved provision of water services (OECD, 2005b). A step-wise approach to upgrading – contingent on what customers could pay for – was adopted, aiming at full cost recovery and at full revenue collection (Secrest, 2001). The review indicated that in many cases these objectives had been met. It has been estimated that in a good number of these countries USD 15-34 per capita per year of additional finance would be needed if the present infrastructure is to be properly maintained and renewed (OECD, 2005b).

The debates concerning the future of water services may in fact be reduced to the question of how, given the rising demands on state budgets, the funding problems are to be resolved and what bodies will be responsible for securing the necessary funding. The problems of maintaining networks are bound up with the question of what future networks will look like (Schramm, 2004). The challenges that the current models of service provision – in particular, public provision – are facing may lead to the adoption of new forms of organisation, operation and ownership of water infrastructure.

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United States

The Constitution provides an overall framework for property rights, while state regulatory commissions oversee the operation of privately owned local utilities and local governments regulate public utilities. With the growth of cities between 1800 and 1900, water provision was dominated by the private owners. By 1900 over half of the concerns were in public ownership due to contractual problems between municipalities and companies, principally over water for fire-fighting. In the United States water and sanitation assets are devolved to local governments. Where local governments have been carved up into smaller political jurisdictions and individual water works are impractical, privately owned companies have emerged to provide regional services covering several local governments. There are approximately 54 000 community water systems, of which some 43% are publicly owned, 33% privately owned and 24% classified as ancillary systems that supply very small communities (Bakker, 2005). Together these systems provide 90% of US tap water; approximately 3 000 provide more than 75%. In addition there are 21 400 non-profit non-community water systems, according to the US Environmental Protection Agency (USEPA). The privately owned water systems are in the main small, user-owned or local investor-owned rather than publicly traded corporations; they supply only some 13% of households. In contrast, public water systems serve 86% of households across America. Private companies are subject to rate-of-return regulation by state public utility commissions, which also oversee the publicly owned utilities.

The estimated water use in 2000 was 1 544 million m^3 per day; use has varied by less than 3% since 1985 as withdrawals for irrigation and power generation have stabilised (Hutson *et al.*, 2005) down from a peak in 1980. Irrigation remains the largest consumptive user; since 1950 it has accounted for 65% of total water withdrawals. Over this period proportionally more water has been withdrawn from aquifers, increasing to 42% of the total in 2000. Irrigated areas more than doubled between 1950 and 1980, remaining stable until 1995; since that year there has been a 7% increase in response to drought conditions, standing now at some 61.9 million acres (Hutson *et al.*, 2005). However, irrigation application efficiency has increased. In 2000, 85% of the population obtained their supplies from public suppliers, up from 62% in 1950, with a corresponding drop in self-supplied domestic usage. Public water supply withdrawals account for some 11% of the total. By contrast, industrial water withdrawals have been decreasing since 1985 (24%), reflecting the changing pattern of industrial activity and the impact of pollution control legislation. California, Texas and Florida accounted for a quarter of all withdrawals, reflecting their usage for irrigation and power generation.

It has been estimated that there are some 1 440 000 km of water mains in the United States; on average there are 238 000 water main breaks each year; and, on average, water systems lose between 20 and 30% of supply, and in the case of older systems as much as 50% (USHR, 2004). Leakage is a serious economic burden. In Detroit for example, there is water rationing and pressure problems in midsummer, and lost water is valued at USD 23 million per year – added to which there are other associated economic costs and health-related issues. There are problems nationwide with the need to replace lead service pipes and measures to reduce their health impact. The cause of the problems is said to be the change in design standards over the years. In the 1890s, systems had design lives of 100 years plus; by the late 20th century this had decreased to between 30 and 50 years (USHR, 2004). Thus many systems are past their sell-by date, as the American Water Works Association observed:

> Considering the huge wave of aging pipe infrastructure created in the last century, we can expect to see significant increases in break rates and therefore repair costs over the coming decades. In the utilities studied by AWWA, there will be a three-fold increase in repair costs by the year 2030 despite a concurrent increase of 3½ times in annual investments to replace pipes. (USHR, 2004)

On top of this there are increasing problems arising from sewers and stormwater. Added to that are the pressures to extend systems and provide additional capacity for supply and sewage systems to cope with growth and the additional operation costs this implies (USHR, 2004). Since 1996, grants for water supply have been made through Congress under the Clean Water State Revolving Loan Funds, which in 2004 amounted to USD 7 billion. Approximately 40% is provided for treatment needs, 30% for transmission and distribution and the remainder for storage, source development and other needs. The amounts are based on USEPA's Drinking Water Needs Survey, carried out every 5 years for the documented needs for the next 5 to 20 years.

The Water Infrastructure Network (WIN) report estimated that drinking water utilities need to spend USD 24 billion per year for the next 20 years on infrastructure, but that currently the expenditure is USD 13 billion per year. In respect of wastewater systems, the USEPA estimated needs in 1998 as requiring a spend of USD 140 billion as part of an assessment for the Revolving Loan Fund programme (UNEP, 2002). More recently the figures given were USD 22 billion and USD 10 billion per year respectively, leaving an overall gap of USD 23 billion per year over 20 years (Johnson, 2004). These amounts dwarf the existing level of funding and federal subsidies used to supplement user fees and help finance capital investments, and are unlikely to address the real causes of inadequate maintenance: the institutional arrangements and managerial practices (Levin *et al.,* 2002). USEPA's own gap analysis, the 2003 Needs Assessment, is in substantial agreement with the WIN and the Congressional Budget Office's estimates (USEPA, 2005). All indicate that there is a need for substantial investments to upgrade or replace water infrastructure (Levin *et al.,* 2002) in order to ensure compliance with quality standards prescribed by the Safe Drinking

Water Act, even though municipal authorities face funding constraints. The current state of water municipalities and increasing public awareness will force federal agencies to implement corrective action at a faster pace. USEPA estimated that drinking water utilities will spend USD 154-446 billion up to 2019 and wastewater systems USD 331-450 billion over the same period in order to meet the required standards. In addition, a further USD 17.5 billion is required to replace lead service pipes and USD 1.2 billion to harden facilities in order to improve security. It has been indicated that in order to meet these demands there will have to be rate increases coupled with increased government funding, as well as more efficient use of water and resources.

Water rates are in the majority of cases insufficient to cover full cost recovery, and their revenues are not hypothecated for reinvestment in water services. Very few utilities have adopted pricing policies that encourage water conservation, such as block tariffs. The number of utilities and the decentralised nature of the industry are also seen as a problem, as they lead to duplication of effort and sub-optimal management of resources, and do not allow for economies of scale to be realised. In recent years there has been an increasing debate about the need to restructure water supply, particularly in light of the forecast needs for high levels of capital. But the evidence on whether public or private provision is better is inconclusive, although private utilities are said to be more successful in raising investment funds (Levin *et al.*, 2002). Land use pressures and economic and social changes will pose challenges to water supply and sanitation systems. The provision of services has prompted massive population transfers to more arid areas and at the same time contributed to increasing per capita rates of consumption, putting further pressure on water resources. There is rising concern that the lack of clean water is becoming a limiting factor for industry; at the same time many communities do not have the ability to pay for the mandated improvements (USHR, 2004). Government loans provide about 10% of the overall infrastructure investment with the remainder provided locally, a situation that is exercising increasing congressional concern over how funding could be more effectively applied (USHR, 2004). Further concerns relate to a severe lack of investment in research and development for the water sector; asset management practices that lag behind other developed countries by some 10-15 years; the need to move towards integrated water resource management in order to address emerging resource and supply issues; and the need for an overhaul of federal financial support mechanisms (USHR, 2004).

Russia

The water sector in Russia is experiencing problems associated with the deterioration of its assets, a lack of management capacity, and weak public finance mechanisms. Many of these problems can be traced back to the late 1980s, when investment in the sector all but stopped. In the last 20 years replacement rates have nowhere exceeded 25% of that needed (Ivanov and Shalukhina, 2005). Water losses between abstraction and consumption are in excess of 50% due to the lack of investment and maintenance. Municipalities are a leading source of water pollution, discharging some 52% of non-compliant wastewater into the environment as some 69% of the systems lack the capacity to treat the current flows. In 1997, 10% of the wastewater requiring treatment was treated to the required standards (NIC, 2000). Urban sprawl from unregulated developments is posing an increasing threat to water sources, especially in Moscow. Drinking water supplies are often contaminated, such that in the 1990s there was a marked increase in water-related diseases. One estimate put the cost imposed by water pollution at 1% of GDP, about USD 13 billion. With only 30% of water consumption metered, revenue collection and conservation is extremely limited, per capita consumption rates are between 450 and 500 l/capita/day. Weak institutional arrangements and a lack of regulation compound the physical problems. In the Soviet era, water services were largely funded from central budgets and industry often provided such services free to the communities around them. Responsibility has now shifted to local governments and public utilities, which lack the ability or political will to generate the necessary revenues. Revenue payments by public entities are often ignored, with the result that the utilities cannot cover operating costs and have to defer still further maintenance and upgrading work (NIC, 2000).

In more recent years the situation has begun to improve with support from the international finance community and the emergence of Russian-owned companies, set up by "oligarch" groups that create joint ventures with municipalities to provide water services (Hall and Popov, 2005). In part this might be the result of legal changes that placed responsibility on local governments for the organisation and development of water services as well as tariff-setting. By mid-2004 private Russian operators controlled 50 large utilities and other municipalities were in the process of negotiating leases or concessions for periods of up to 50 years. Such contracts are subject to minimal controls, which increase the risks to all parties – and most especially consumers – considerably. Increasingly, finances such as loans are being provided by international organisations such as the World Bank, EBRD, EU and the International Finance Corporation. An example of such initiatives is the EBRD support for the St. Petersburg sewage plant to treat effluent from 77 000 people; as a result only 15% of the city's wastewater is now untreated, contributing to tackling the environmental pollution of the Baltic Sea. The EUR 138 million project was supported by a loan of EUR 35 million from the EBRD and EUR 50 million donor funding from the EU. Most of the international agencies' efforts are focused on promoting the introduction of the private sector or corporatisation and thus include sectoral reform as well as infrastructure upgrading as part of the project finance (Hall and Popov, 2005). Major water MNCs have generally not entered the Russian market for a variety

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of reasons, though a number have contracts to build and operate works. These include the risks to returns, local opposition and legal obstacles. They have however been increasing their co-operation and partnerships with Russian companies in the sector, providing engineering and consultancy expertise.

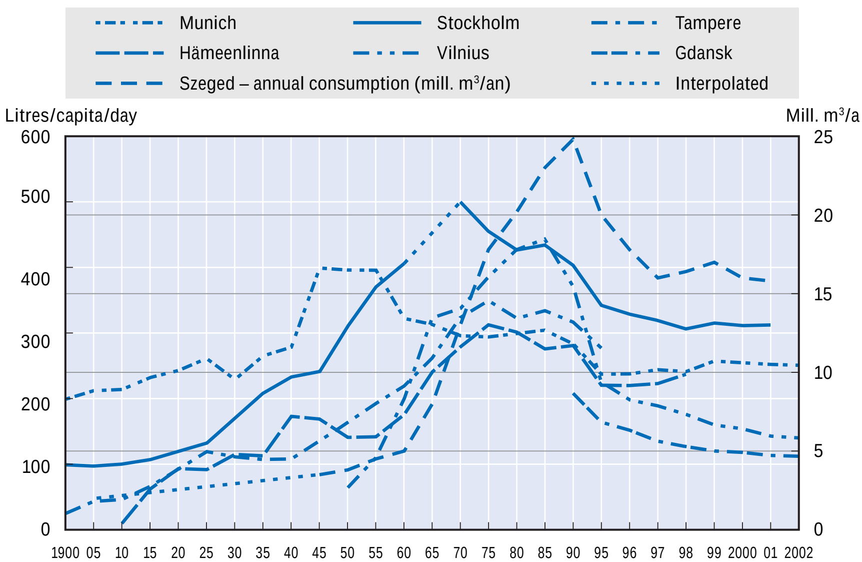
The estimated investment required to replace water works and installations runs at USD 10 billion. To be able to cover such expenses over ten years would require tariff increases of 4 times present levels. In view of such high amounts other sources of funding need to be identified. For full water meter penetration an amount of USD 200 million has been estimated along with USD 50 million annually to service such a system. It has been anticipated that in the medium term there could be up to ten large local companies managing water services to the majority of Russian towns and cities.

Africa

Africa has the lowest proportional coverage of the population with access to improved water supply of any region of the world. The situation is much worse in rural areas, where coverage is 50% compared with 86% in urban areas. Sanitation coverage in Africa is also poor, although Asia has even lower coverage levels. Currently, only 60% of the African population has sanitation coverage, with 80% and 48% in urban and rural areas respectively. In global terms, the continent houses 27% of the world's population that is without access to improved water supply, and 13% without access to improved sanitation. The African population is expected to increase by 65% over the next 25 years, with the greatest increases in urban areas. The urban population is expected to triple, from some 138 million in 1990 to 500 million in 2020, with 20% of the population – some 200 million – living in a few megacities. In 1990 the largest megacities (25 million) accounted for half or more of the GDP. Meeting the 2015 MDG targets will require tripling the rate at which additional people gained access to water between 1990 and 2000, and quadrupling the rate at which they attained improved sanitation. Whereas 86% of urban dwellers have "improved" supplies, more than half have inadequate provision if the definition is to mean a house connection or yard tap. In most of the largest cities in Africa, less than 10% of the inhabitants have sewer connections. Tens of millions of households, especially in informal settlements, only have access to overused and poorly maintained communal or public toilets. Supplying the burgeoning cities is placing increasing strain on hinterlands, with many cities already outgrowing the local resources. In addition to deleting water resources, associated resource stripping has resulted in excess runoff, soil erosion and subsequent receiving water sedimentation and contamination. Water-stressed areas already exist in several major river basins, *e.g.* the Nile, Tana, Limpopo and Niger. Many of these are also experiencing problems due to trans-boundary issues between countries, as is Lake Victoria (Ray and Dzikus, 2000).

ANNEX 5.A1

Figure 5.A1.1. **Water consumption patterns for some European cities – total water supplied per capita**



Source: P.S. Juuti and T.S. Katko (eds.), *Water, Time and European Cities*, Figure 17, p. 232.

Table 5.A1.1. **Changes in household water use for EU countries**

Litres/head/day

Country group	Mid-1980s	End-1990s-2000
Nordic	175	195
Southern	180	178
Western	140	147
All member states	148	150
New (then) accession countries	125	108

Source: Wieland, 2003.

Table 5.A1.2. **EU Domestic water consumption per capita per year (m^3)**

Data from late 1990s and 2002

Comparative use	Countries	Domestic use	% population connected to public water supply
Highest users	Finland, Italy, Spain, Portugal, Greece	64-78	85-100 (some countries not known)
Mid-level users	Denmark, Luxembourg, Austria, Sweden, Romania	55-60	54-97
Lowest users	Belgium, France, Netherlands, Germany, Slovenia	41-47	91-99.9
EFTA users	Iceland, Norway, Switzerland	75-108	89-95

Source: Vall, 2001; Eurostat.

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TELECOM, LAND TRANSPORT, WATER AND ELECTRICITY

Infrastructures are the very foundation of modern economies and societies. Energy, transport, water, telecommunications, all will continue to be essential to future development and growth. However, infrastructure investment requirements over the coming decades will be massive, running into trillions of dollars. Part of this investment will be in the developing world, especially in the major economies such as China, India and Brazil. But OECD countries, too, will account for a huge share, much of it in infrastructures that have been seriously neglected in many countries, *e.g.* water and waste water treatment.

How will the investments be financed, given that OECD populations are ageing fast and public finances tightening? How will such factors as urbanisation, climate change and globalisation affect the development of infrastructures in OECD countries? How will the role of the public sector and private actors evolve over time? These are just some of the questions this OECD report addresses in its long-term assessment of the future of infrastructures.

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